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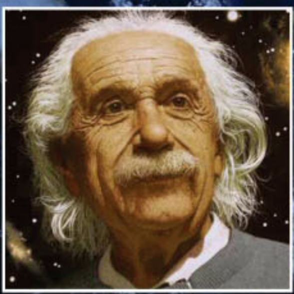

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This month's stunning planetary conjunction

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Welcome

We're standing on the brink of space exploration's golden age

On Tuesday 24 May 2005 our first issue went on sale. In those days Pluto was still a planet, and the study of exoplanets was still in its infancy. Ten years later we're still going strong, Pluto is about to receive its first direct flyby, and the number of confirmed alien worlds has risen to almost 2,000.

To celebrate our 10-year anniversary we asked Prof Martin Rees, the Astronomer Royal, to edit this issue. In discussing what should be covered he was keen to look forward to plans for the next decade and beyond, rather than look back over the past. It is a remarkable time for the science of astronomy, when technologies are coming of age, engineering advances are enabling increased capability in hostile environments and the connections between scientific disciplines are reaping more and more rewards. On the next page, Prof Rees introduces the features he has chosen for this special issue, which explain why we stand on the brink of a new golden age of space exploration. For my part, it has been incredibly rewarding to cover the great discoveries in space science over the past decade, and I look forward to the covering the amazing advances over the next 10 years.

Enjoy the issue!

Chris Bramley Editor

PS Next issue goes on sale 18 June.

This month's contributors include...

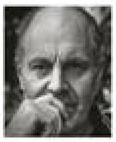
MAGGIE ADERIN-POCOCK
SKY AT NIGHT PRESENTER

Maggie takes a look at the mysteries of Earth's 'twin' planet, the hellishly hot Venus. *Page 23*

JAMES L GREEN
PLANETARY SCIENTIST

The director of NASA's planetary science division outlines the agency's plans to explore Mars in the next two decades. *Page 36*

MARK MCCAUGHREAN
SPACE SCIENTIST



ESA's senior science advisor in the directorate of science and robotic exploration on why we must keep exploring. *Page 42*

ANATOLY ZAK
SPACEFLIGHT EXPERT

How the ambitions of the Soviet Union launched the Space Race and paved the way for the ISS. *Page 77*

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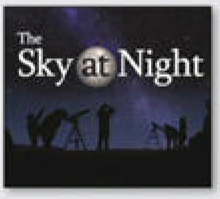
Sky at Night LOTS OF WAYS TO ENJOY THE NIGHT SKY...



TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 21

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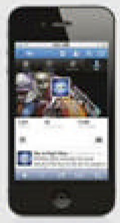

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“Had the pace of the Apollo programme been maintained, there would have been footprints on Mars by now”

Our 10th anniversary issue is guest edited by **Martin Rees**, the Astronomer Royal, professor of cosmology and astrophysics at the University of Cambridge and past president of the Royal Society

Unless you are now middle-aged, you're too young to remember the blurred TV images of Neil Armstrong's 'one small step' – and the accompanying rapid-fire commentaries by Patrick Moore. The Moon landings were a massive achievement, and came only 12 years after the launch of the Soviet Sputnik – the first man-made object to go into orbit. Had the pace (and huge expenditure) of the Apollo programme been maintained, there would have been footprints on Mars by now.

But the prime US motivation for Apollo wasn't science, or exploration: it was to 'beat the Russians'. So the momentum wasn't sustained thereafter, and it's now more than 40 years since humans have ventured beyond low-Earth orbit. Will a renewed surge in manned spaceflight be spearheaded by China? Or will it be left to private adventurers, prepared to cut costs and take high risks? We don't know. But in either case it will build on the heroic legacy of what the two 'superpowers' did during the Cold War. That's why we should welcome the Science Museum's forthcoming exhibition 'Cosmonauts: Birth of the Space Age', which will highlight Russia's early 'firsts' – read more about those on page 77 – and their sustained programme of long-duration flights.

Thanks primarily to NASA and ESA, unmanned exploration of the Solar System has advanced apace in the past four decades.

DAVE CAUDERY X 4

Top to bottom: Martin and editor Chris Bramley met at the Royal Society to work up the contents of this anniversary issue

Curiosity is trundling across the Martian surface; Cassini has spent years exploring Saturn and its moons. Later this year we'll have our first close-ups of Pluto, and Rosetta's cameras will reveal how a comet warms (and perhaps breaks up) as it nears perihelion. And we can look forward to a succession of future planetary missions, explored further on page 35.

We've learnt in the past decade something that makes the night sky hugely more fascinating. Most stars are, as the Sun is, orbited by retinues of planets. Our Milky way probably harbours billions of Earth-like planets. Before the James Webb Space Telescope and the next generation of 30m class ground-based telescopes come online, it's important to survey the whole sky to find the closest and most interesting systems for these hugely powerful instruments to focus on, and we speculate on that future on page 106.

In scanning the extragalactic realm, orbiting X-ray telescopes probe ultra-hot gas swirling into monster-sized black holes. ESA's Planck spacecraft has revealed clues to the era when our entire observable Universe was of microscopic size. The equipment that enables these discoveries is a lucky spin-off from technologies developed for more lucrative practical purposes. Indeed our everyday life now depends on flotillas of spacecraft – for communications, environmental monitoring and SatNav. The engineers and instrument builders deserve most credit. Armchair theorists by themselves wouldn't have accomplished much.

This year is the centenary of the greatest-ever achievement of armchair theory: Einstein's general relativity, which we look back at on page 71. This theory is crucial to our understanding of the Big Bang, black holes, and other exotica. But some are surprised to learn that this seemingly arcane theory is important to everyday life. The clocks in GPS satellites are affected by Earth's gravity, and SatNav wouldn't be accurate unless the relativistic effects were allowed for. This exemplifies the interconnectedness of science – and highlights the manifold motives for our fascinating quest to explore the cosmos and our place in it.

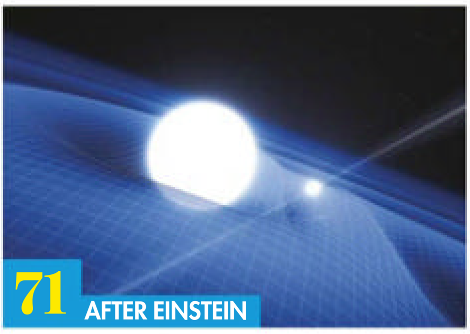
It is my hope that the features in this issue inspire you and explain why it is vital that we continue to explore space and the boundaries of scientific knowledge. I look forward to reading of these ground-breaking discoveries in *BBC Sky at Night Magazine*'s next decade.

In the magazine

NEW TO ASTRONOMY?
See *The Guide* on page 82 and our online glossary at www.skyatnightmagazine.com/dictionary

FEATURES

C = on the cover



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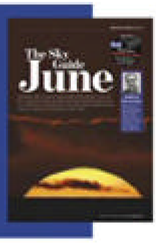

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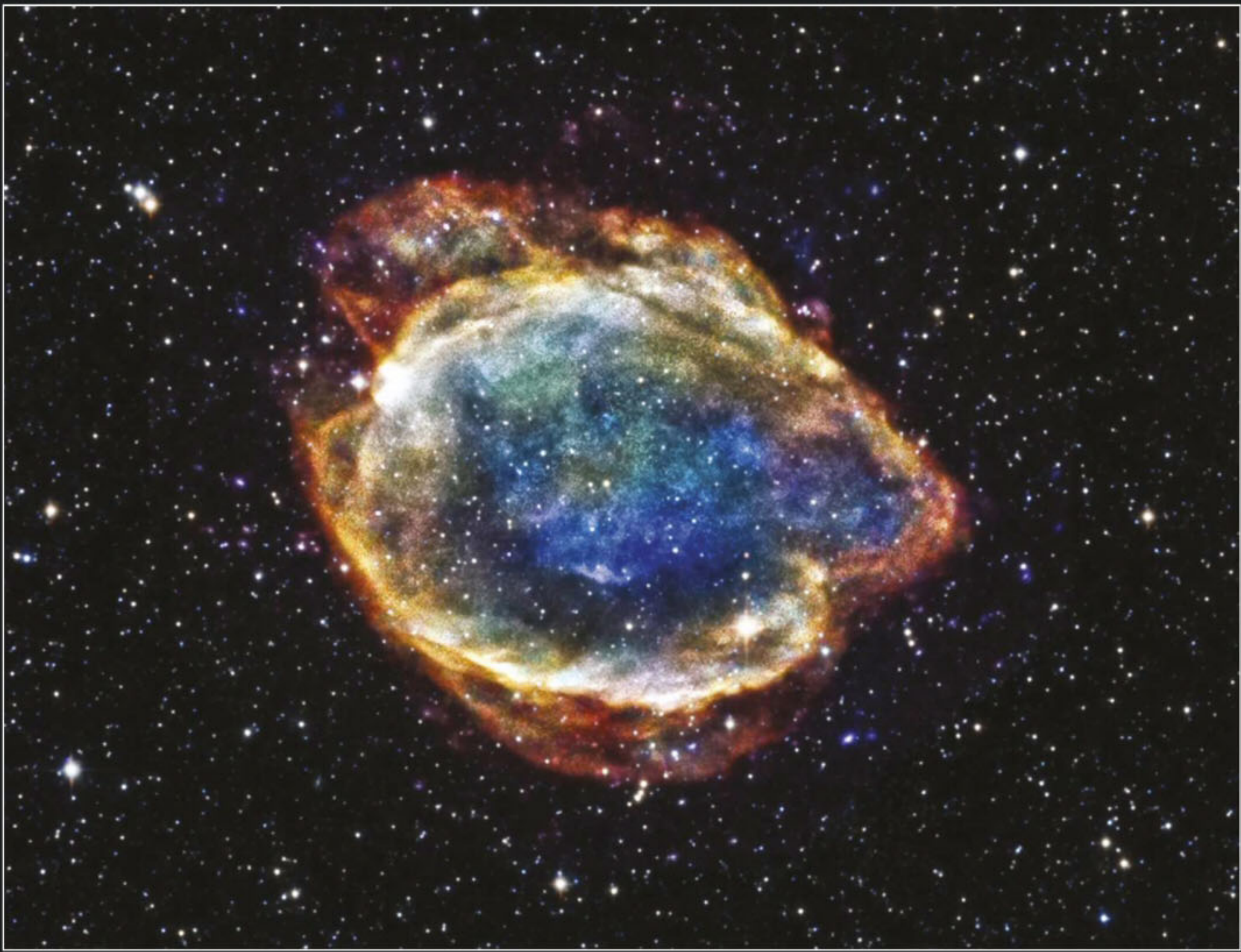
Beyond the Trifid

VISTA, 4 FEBRUARY 2015

An infrared glimpse of this famous nebula reveals a hidden starscape

The Trifid Nebula, M20, is a familiar sight to most deep-sky enthusiasts, but in this infrared image – taken as part of the VVV (Vista Variables in the Via Lactea) survey – it glows a lot less brightly than usual. That's not a bad thing, though: by observing in the infrared, astronomers are able to see objects lying beyond the nebula that are normally hidden from our view. And by revisiting the same area of sky multiple times, they can spot objects that vary in brightness. As a result, two very distant Cepheid variables feature in this picture that have never been imaged before.

ESO/VVV CONSORTIUM/D. MINNITI



▲ What's left behind

CHANDRA X-RAY OBSERVATORY, 12 FEBRUARY 2015

Who would have thought the aftermath of a thermonuclear explosion could be so beautiful? Seen here in false colours representing the infrared, optical, ultraviolet and X-ray spectra is G299.2-2.9, the remnant of a Type Ia supernova that occurred around 4,500 years ago. Type Ia remnants are usually symmetrical; G299.2-2.9 isn't, so astronomers hope that studying the object will reveal more about these rare events.

▼ Valley view

MARS EXPLORATION ROVER OPPORTUNITY, 13 MARCH 2015

This inhospitable landscape is Marathon Valley on Mars, a region on the western rim of the Endeavour Crater. Observations by the Mars Reconnaissance Orbiter have revealed that the region is rich in clay minerals – evidence of Mars's wetter past. This true-colour image spans east to southeast and was taken just before Curiosity's total distance travelled on Mars reached 26.2 miles – hence the valley's name.

◀ Distant spiral

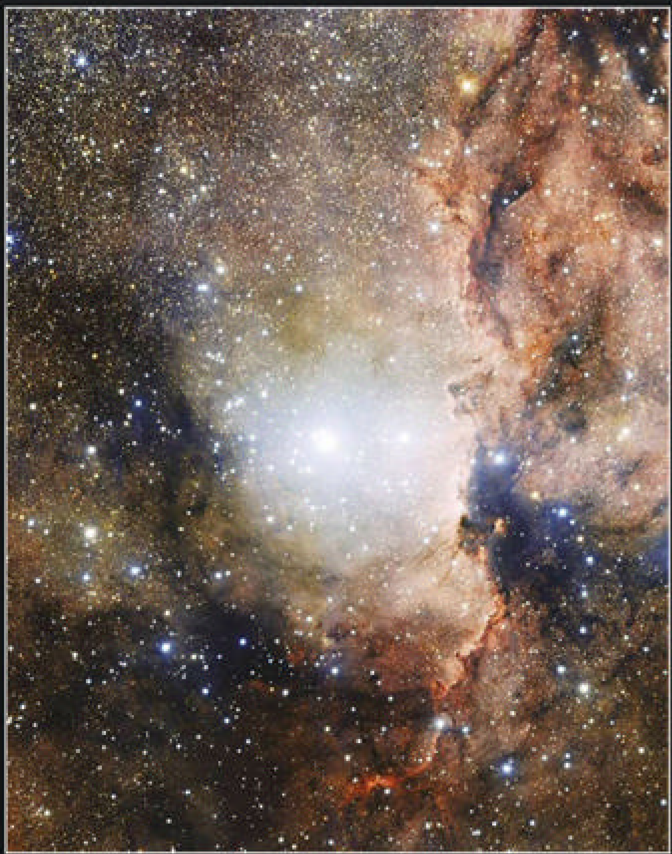
HUBBLE SPACE TELESCOPE
30 MARCH 2015

Seen here is NGC 3021, a spiral galaxy in the constellation of Leo Minor, the Little Lion. Lying 100 million lightyears from Earth, NGC 3021 contains several Cepheid variable stars – the 'standard candles' used to measure distances in deep space – and in 1995 was also the site of a Type Ia supernova, an even brighter marker that can be used to measure even greater distances.

Jewels of the Altar ▶

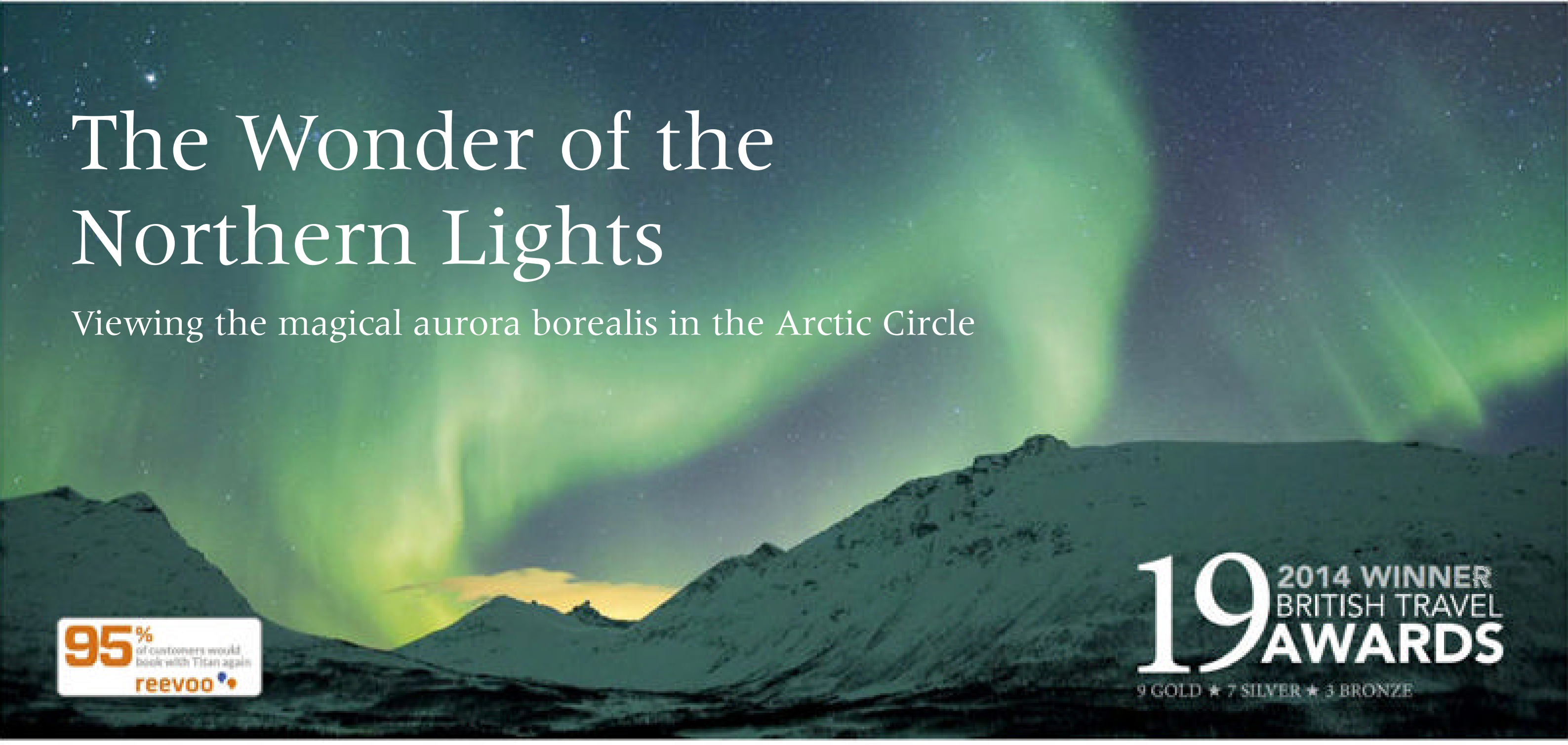
VLT SURVEY TELESCOPE, 11 MARCH 2015

The southern constellation of Ara, the Altar, is rich in celestial delights, and this is the most detailed image of the region captured to date. At the centre is open star cluster NGC 6193, which contains around 30 bright stars that illuminate the Rim Nebula, NGC 6188, sitting to the right of this picture. The entire region is rich in hydrogen, and so new stars are forming here constantly.



The Wonder of the Northern Lights

Viewing the magical aurora borealis in the Arctic Circle



The awe-inspiring spectacle of the Aurora Borealis (Northern Lights) has held watchers spellbound since the dawn of human history. Countless legends arose to explain these extraordinarily beautiful swirls of greens, yellows and reds shimmering against the night sky, from celestial dragons to the spirits of vanquished warriors. Knowing their scientific origin - as charged particles borne on solar winds to the earth's magnetic pole - in no way detracts from their magnificence or modern-day appeal. Our fascinating cruise itinerary, set entirely within the Arctic Circle aboard one of Hurtigruten's excellent vessels, maximises the likelihood of experiencing this mesmerising phenomenon.

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Day 4 Kirkenes - Berlevag. We arrive in the sheltered harbour of Kirkenes, a mere 10km from the Russian border and the Sami communities of Northern Finland. Whilst here, there is the opportunity to join an optional excursion to visit the amazing Snow Hotel. Our adventure continues this afternoon as we sail southwards, crossing Varangerfjord, a fabled bird-watching site.

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Bulletin

The latest astronomy and space news written by **Hazel Muir**

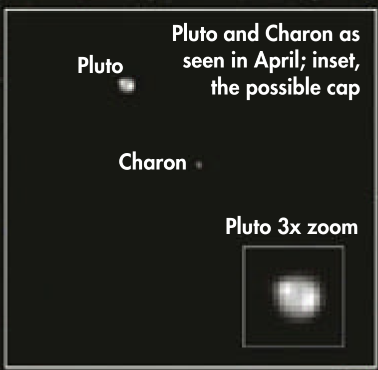
PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

Countdown to Pluto

Expect surprises from New Horizons when it reaches Pluto in July

NASA'S NEW HORIZONS spacecraft has spotted a bright area on one of Pluto's poles – could it be that this dwarf planet has an ice cap? The gleaming spot was revealed in our closest ever image of the dwarf planet – shown inset – which is just a taste of what is to come as the mission approaches the dwarf planet. The probe will fly past on 14 July at a distance of around 12,500km.



Pluto and Charon as seen in April; inset, the possible cap

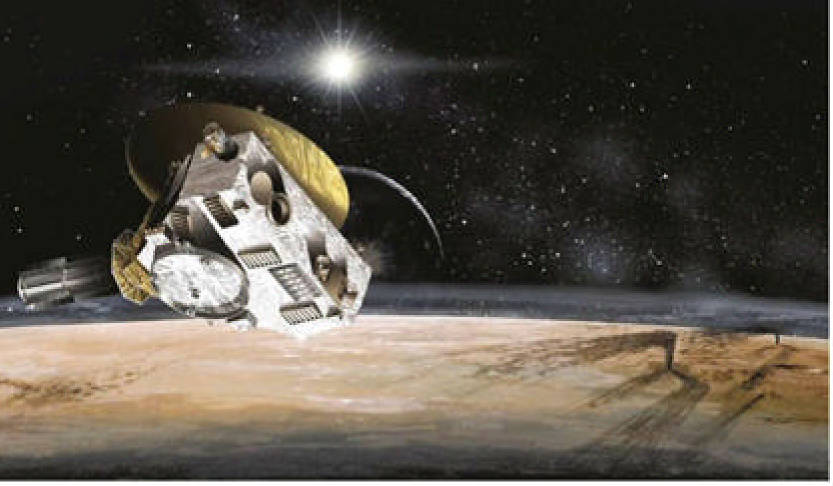
"There's so much we don't know, not just about Pluto, but other worlds like it," says mission scientist Hal Weaver from Johns Hopkins University in Maryland. "We're not rewriting textbooks with this historic mission – we'll be writing them from scratch."

New Horizons will also image Pluto's moons. When NASA approved the mission in 2001, astronomers had only identified one moon, Charon, which was discovered in 1978. Since then, they have identified four smaller moons, although little is known about them.

"This is pure exploration – we're going to turn points of light into a planet and a system of moons before your eyes," says Alan Stern from the Southwest Research Institute in Colorado, chief scientist for New Horizons. "This 21st-Century encounter is going to be an exploration bonanza."

Observations so far suggest that Pluto has intriguing surface markings and a complex nitrogen atmosphere that changes with the seasons. Its interior may harbour a liquid ocean. Charon itself might sport an atmosphere or an interior ocean, and New Horizons will look for evidence of recent activity on its surface.

▸ See Comment, right


New Horizons has taken nine years to reach the dwarf planet; when it launched, Pluto had only one known moon

NASA/JHU-APL/SWRI

COMMENT
by Chris Lintott

It is time for us to place our bets – what will this mysterious world will turn out to be like? The smart money seems to be looking toward Neptune's moon Triton, which Voyager 2's flyby in the 1980s revealed was surprisingly active. Triton has a scarred yet extremely young surface, bearing the traces of a complex recent history, which includes erupting ice volcanoes, several of which were observed by the spacecraft.

Triton has obviously had a very different life, having been captured by Neptune, but it probably started in the Kuiper Belt where Pluto now lives. Pluto is believed to have suffered a violent collision, producing Charon and perhaps its other moons, but Triton too is expected to have collided with something on its way into the Neptunian system. Predictions at this stage are probably foolish, but my guess is that Pluto, like Triton, will be a surprisingly interesting and perhaps even active world.

CHRIS LINTOTT co-presents *The Sky at Night*

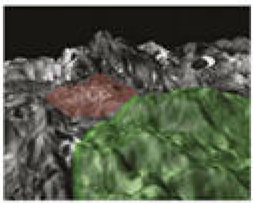
NEWS IN BRIEF

MESSENGER ENDS ITS MISSION

NASA's Messenger spacecraft has crashed onto Mercury after running out of propellant. The probe had orbited the planet from 2011; in 2012, it provided evidence that Mercury harbours abundant frozen water in permanently shadowed polar craters. "We are celebrating Messenger as more than a successful mission," says John Grunsfeld from NASA Headquarters in Washington DC. "It's the beginning of a longer journey to analyse the data that reveals all the scientific mysteries of Mercury."

MOON ERUPTION LARGER THAN POMPEII

A huge volcanic eruption on the Moon 3.5 billion years ago spread debris over an area much greater than previously thought, throwing rock five times farther than the eruption that buried the Roman city of Pompeii. "Radioactive rock was thrown far beyond the slopes of the volcano, reaching several hundred miles in one direction," says Jack Wilson from Durham University.



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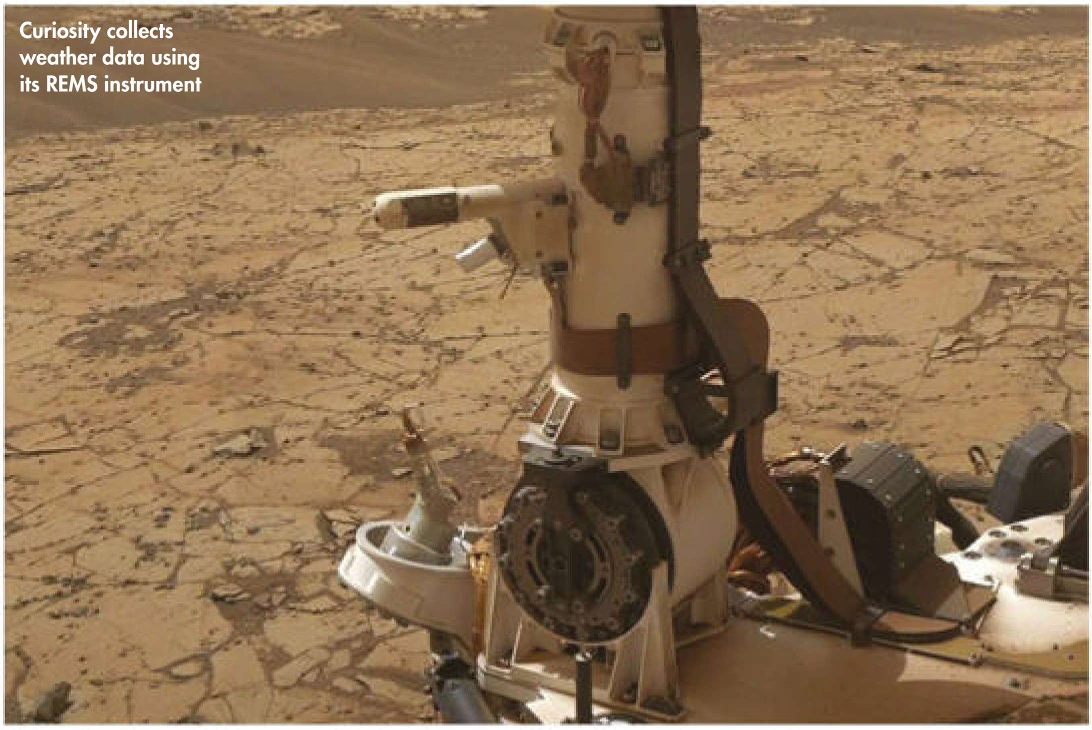


Curiosity collects weather data using its REMS instrument

Water often flows on Mars

Dark regions of the Red Planet may be patches of damp soil

A SURPRISING AMOUNT of liquid water may exist on Mars during its warmest seasons, according to new calculations. Conditions might be favourable for the formation of briny liquid in Martian soil, extending closer to the planet's equator than expected.

NASA's Phoenix Mars Lander and the Curiosity rover identified the salt perchlorate in Martian soil. This chemical can absorb water vapour from the atmosphere and lower the freezing temperature of water, like antifreeze. It was thought to explain the possible existence of transient liquid brines at high latitudes on Mars, despite its cold and dry conditions.

Observations have backed this up. NASA's Mars Reconnaissance Orbiter has spotted many sites on Mars where dark streaks appear on slopes during warm seasons. Scientists suspect that they form when humidity just above the ground reaches a critical threshold level. Salts like perchlorate, which may be present in soils all over the planet, could then absorb enough water to become dissolved in liquid, a process called 'deliquescence'.

Now Javier Martin-Torres from the Spanish Research Council and colleagues have analysed temperature and humidity measurements by Curiosity for more than a Martian year. The probe landed in Mars's Gale Crater in 2012.

Their new calculations suggest that surprisingly, conditions at the rover's near-equatorial location are favourable for small quantities of brine to form during some nights throughout the year. It would then dry out again after sunrise.

"Gale Crater is one of the least likely places on Mars to have conditions for brines to form, compared to sites at higher latitudes or with more shading. So if brines can exist there, it strengthens the case that they could form and persist even longer at many other locations," says team member Alfred McEwen from the University of Arizona in Tucson.

"Liquid water is a requirement for life as we know it, and a target for Mars exploration missions," adds Martin-Torres. He stresses that conditions near the surface of Mars still seem too harsh for microbial life to flourish, but further studies of liquid brines on the planet could raise interesting questions about Mars's habitability and geological changes over time.

www.nasa.gov/curiosity

Type Ia supernovae like SN 2014J in M82 may not be as reliable as we thought

Doubts cast on Universe's acceleration

Cosmic expansion may not be quite as fast as we believe it to be

THE UNIVERSE MIGHT not be expanding as fast as astronomers suspected. Doubts have been raised as one of the tools for measuring the expansion speed, the brightness of Type Ia supernovae, seems to be less reliable than assumed.

Type Ia supernovae occur when a white dwarf becomes unstable and explodes. The explosions were thought to have a very standard intrinsic brightness, allowing astronomers to measure their distance and hence the scale and expansion rate of the Universe, which seems to accelerate due to a mysterious effect dubbed 'dark energy'. Now, however, a team led by Peter Milne from the University of Arizona has used observations from Hubble and NASA's Swift satellite to show that the supernovae have two separate brightness categories. "This research doesn't suggest there is no acceleration, just that there might be less of it," says Milne.
www.hubblesite.org

DOES DARK MATTER FEEL ANOTHER FORCE?

FOR THE FIRST time, dark matter may have been seen interacting with itself through a force other than gravity. The finding comes from observations of colliding galaxies 1.4 billion lightyears away.

Around 85 per cent of the mass of the Universe is dark matter, a mysterious unidentified substance that emits no light. However, its gravity influences the motion of galaxies and the path of light coming from background galaxies.

Richard Massey from Durham University and colleagues studied four colliding galaxies using the Very Large Telescope in Chile and the Hubble Space Telescope. Their analysis suggests that one dark matter clump lags behind the galaxy it surrounds, which fits with theories that dark matter can interact with itself due to a force other than gravity. "We used to think that dark matter just sits around, minding its own business, except for its gravitational pull," says Massey. "But if dark matter were slowed down during this collision, it could be the first evidence for rich physics in the dark sector – the hidden Universe."
www.eso.org/vlt

The findings are based on observations of four colliding galaxies within Abell 3827

NEWS IN BRIEF

CASSINI RETURNS TO ICY MOONS

NASA's Cassini spacecraft is set to return to the realm of the planet's icy moons, beginning with Rhea. For the past two years, the probe's orbit carried it high above the planet's poles, limiting its ability to encounter any moons apart from Titan. But Cassini's orbit will remain nearly equatorial during 2015, leading to four close encounters with Titan, two with Dione and three with Enceladus, the enigmatic moon famous for its geysers.

CARBON EXPLAINS MERCURY'S DARKNESS

Mercury's curiously dark surface may have finally been explained: it may be due to carbon delivered by comets and cometary dust. Calculations by Megan Bruck Syal from Lawrence Livermore National Laboratory in California and colleagues suggest tiny meteors from comets create surface carbon abundances of up to six per cent on the planet. "This implicates carbon as a 'stealth' darkening agent that's difficult to detect with available remote-sensing methods," she says. "Mercury is effectively painted black."

CUTTING EDGE

Our experts examine the hottest new research

There's something in the air

Looking for out of kilter exoplanet atmospheres may be the key to finding life on other planets

▲ Water is critical to the survival of life as we know it; this paper reinforces the idea that it has a huge effect on a planet's atmosphere

ISTOCK

It is a centuries old question: how is it possible, from a distance of hundreds of lightyears, to find life on another planet? The starting point might be to look for the things that all life has in common, and the authors of this month's paper, led by Joshua Krissansen-Totton of the University of Washington in Seattle, begin with the idea that what ties all life together is waste. Specifically, waste gases produced by even simple life forms, present in a planet's atmosphere as a long-lasting trace of what's going on underneath.

This is not a new idea, but with telescopes now under construction that might actually be able to measure the composition of a planet's atmosphere, it may well be one whose time has come. Previous work is old enough that we didn't even know the composition of our own Solar System's planets in detail when it was done, whereas now researchers can draw on in situ observations such as those made by the Curiosity rover at Mars.

So how do you identify an atmosphere that's been affected by life? The idea is that you might look for anything out of equilibrium: left alone for long enough, a system of chemicals will evolve towards a mixture whose composition can be predicted. Any source of chemicals – like belching bacteria – will stand out as a disruption of this mixture.

The trouble is there are other processes to consider. Sunlight, for example, can break up molecules in the atmosphere, leading to further reactions. Indeed, the energy provided by the Sun is enough to drive the chemistry in Earth's atmosphere permanently away from equilibrium, even if there was no life. What the researchers do, however, is measure how far away from equilibrium each planet and moon in their study is.

They look at Earth, Mars, Venus, Jupiter, Uranus and Titan, and if this is to be an effective means of detecting life on exoplanets then you would expect Earth to stand out. When the results are first presented, our planet doesn't stand out at all – the strong influence of the Sun on Mars's thin atmosphere, for one, creates a much larger impression than life does on Earth's air.

Writing off the technique is premature, though, for the researchers check their numbers again but this time include the effect of the oceans. The presence of liquid water fundamentally changes the chemistry of the atmosphere, and when this is included then the effect of the Earth's biosphere is obvious. In particular, the failure of oxygen and nitrogen to react is the smoking gun; without life, both would nearly vanish in two hundred million years or so. That sounds like a long time, but geologically it's fast. Life on Earth has been affecting the atmosphere for billions of years, and it seems that in all that time it may have been signalling its presence to alien astronomers.

> "How do you spot an atmosphere affected by life? Look for anything out of equilibrium"

Before we rush to the telescope, there is much work still to do. Applying the technique does require knowing, from some independent measurements, that oceans are present, but there are ideas about how to do that. Probably the biggest hole is that the work doesn't include reactions that take place between solid rock and atmospheric gases, which complicate things even more. This is a great start, though, and a fascinating modern look at some of astrobiology's beginnings.

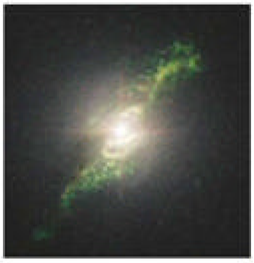
CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading…
On detecting biospheres from thermodynamic disequilibrium in planetary atmospheres by Joshua Krissansen-Totton, David S Bergsman and David C Catling
Read it online at http://arxiv.org/abs/1503.08249

NEWS IN BRIEF

DEAD GALAXIES HAVE ODD GREEN WISPS

Astronomers have spotted around 20 wispy, green objects thought to be the remnants of energetic galaxies that have faded. Bill Keel from the University of Alabama identified them with the help of 200 volunteers using observations by Hubble and ground-based telescopes. The green wisps were probably illuminated by ultraviolet radiation that once emerged from each host galaxy's core, then weakened. The glowing structures have looping, helical and braided shapes; some of them are tens of thousands of lightyears long. "They don't fit a single pattern," says Keel. "This is a record of something that happened in the past."



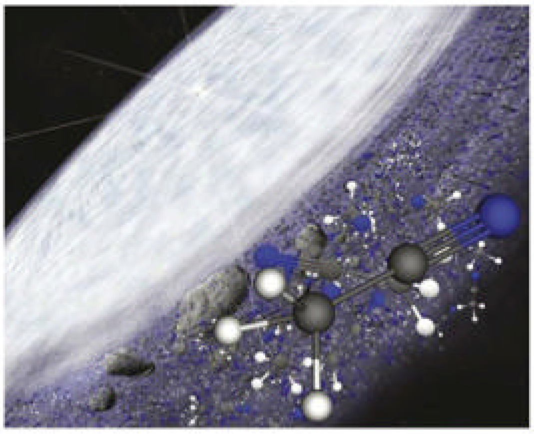
DESIGN BEGINS FOR ASTEROID IMPACT MISSION

Two design concepts for ESA's Asteroid Impact Mission (AIM) are now being worked on by European consortia. AIM will visit and map a distant asteroid, then watch as another spacecraft is crashed into it.

NASA/ESA AND W. KEEL (UNIVERSITY OF ALABAMA/TUSCALOOSA), ESA-SCIENCE OFFICE, B. SAXTON (NRAO/AUI/NSF), NASA, RUTHERFORD OBSERVATORY

New hope for alien life

Complex organic molecules could be commonplace



▲ **The molecules were found far from the star, in a region thought to be analogous to our own Kuiper Belt**

ASTRONOMERS HAVE DISCOVERED complex organic molecules in a dusty disc surrounding a young star 455 lightyears away. A team led by Karin Öberg from the Harvard-Smithsonian Center for Astrophysics in Massachusetts used ALMA in Chile to show that the disc, which may go on to form planets, contains large amounts of methyl cyanide – enough to fill all of Earth's oceans. This proves that complex organics needed for life are not unique to the Solar System – Methyl cyanide contains carbon-nitrogen bonds, essential for the formation of amino acids. "Once more, we have learnt that we're not special," says Öberg. "From a life in the Universe point of view, this is great news."
www.almaobservatory.org

NASA APP LETS YOU VISIT VESTA

NASA HAS RELEASED a free app called Vesta Trek that allows you to virtually fly around and skim the surface of one of the largest asteroids in our Solar System.

NASA's Dawn spacecraft studied Vesta from July 2011 to September 2012. Its observations have been compiled into Vesta Trek, which includes interactive maps, topography and mineralogy details, and ways to measure the size of surface features, operated by a user friendly set of tools. "There's nothing like seeing something with your own eyes, but these types of detailed data visualisations are the next-best thing," says Kristen Erickson from NASA headquarters in Washington DC.
http://vestatrek.jpl.nasa.gov

The NASA app allows users to explore Vesta's surface just like Dawn did prior to its trip to Ceres

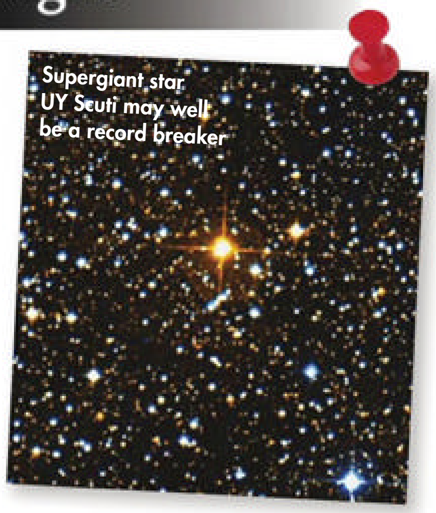
Looking back The Sky at Night

June 1958

On 20 June 1958, *The Sky at Night* broadcast discussed dwarf and giant stars. Danish astronomer Ejnar Hertzsprung coined these terms in the early 1900s when he noticed that red stars fall into two distinct categories, some being much brighter than the Sun (giants) and others much fainter (dwarfs).

Today dwarf stars are classed into many categories, including white dwarfs, which are the shrunken remains of Sun-like stars that have run out of fuel, and brown dwarfs, the failed stars that are too small and cool to have ignited hydrogen fusion in their cores.

Giant stars are up to a few hundred times as wide as the Sun and they can have luminosities a few thousand times higher. 'Supergiants' include UY Scuti, a bright red pulsating variable star that's currently a leading contender for the largest known star by radius.



Supergiant star UY Scuti may well be a record breaker

CUTTING EDGE

Our experts examine the hottest new research

Growing Martian moons

The origin of Mars's two moons has long been a mystery, but a fresh simulation may hold the answer

There has been an ongoing debate for a long while now as to where Mars's two moons came from? One idea is that Phobos and Deimos were both passing asteroids that got caught by the Red Planet's gravity. They both certainly look like asteroids in terms of their size and appearance – dark-coloured, potato-shaped chunks of rock. But size and shape don't make for clues here. Any rocky object, whether it formed as an asteroid orbiting the Sun or in a dusty disc orbiting a planet as a moon, will most likely be an irregular, lumpy, potato-shaped object, unless it is big enough to pull it into a spherical ball.

The alternative explanation, and one that has been steadily gaining ground recently, is that the twin moons both formed from a disc of debris swirling around Mars that was thrown up into space by a giant impact, similar to how our own Moon was created. This theory neatly explains why both moons have circular equatorial orbits.

NASA/USGS X 3

LEWIS DARTNELL is an astrobiologist at University of Leicester and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

Furthermore, measurements by orbiting Mars probes have indicated that the composition of the two moons is unlike that of asteroids and meteorites, but that they do share some of the same minerals as found on the Martian surface. It's seeming increasingly likely, then, that rather than being captured interlopers, Deimos and Phobos were both formed by stuff pinched off the face of Mars.

The potential problem with this re-accretion hypothesis, though, is that it requires enough moon-making material to be flung off Mars by an impact. To look into how substantial a debris disc can be formed from impactors of different sizes and speeds slamming into Mars, Robert Citron at the University of California and his colleagues used a computer model of giant collisions and the material spraying up from the crater to calculate how much material forms into a swirling disc, rather than rapidly falling back down to the surface or flying so fast that it's ejected from the system altogether. In particular, Citron wanted to investigate whether the

> "They certainly look like asteroids – dark-coloured and potato-shaped chunks of rock"

huge, 8,000km-wide basin covering the northern hemisphere of Mars – called the Borealis Basin – was itself formed by a giant impact; and if that was the case, could it also have flung out enough material to form a big enough debris disc in orbit to form the moons. For that to happen, the scenario is a rocky body about 1/40th the mass of Mars hitting the planet at just over 24,000km/h.

What they found is that a giant impact capable of gouging out the Borealis Basin would have lofted enough material to form a debris disc between one and four per cent of the impactor's mass – which equates to 500 billion billion kilograms of pulverised rock in Martian orbit. The authors say that such a dense debris disc would be sufficient to form at least one of the moons. Now their results can now be used by other simulations focusing on how that disc develops over time to produce moons.

LEWIS DARTNELL was reading…
Formation of Phobos and Deimos via a giant impact
by Robert Citron, Hidenori Genda and Shigeru Ida
Read it online at http://arxiv.org/abs/1503.05623v1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What's on

Our pick of the best events from around the UK

Summer Solstice Day

PICK OF THE MONTH

Royal Observatory Greenwich, London, 21 June, 1pm-4pm

▲ The Royal Observatory's solstice celebration offers a chance to use its telescopes

As we reach the height of summer, attention turns to 21 June and the solstice that marks the beginning of darker evenings and shorter days, anticipating our progression into autumn and winter. This year, the Royal Observatory Greenwich is marking the occasion with a day of events focused on the Sun. Activities include the chance to use solar telescopes and attend workshops on solar astrophotography. There will also be an opportunity to look at historic solar instruments, and talks on solar physics and the history of solar observing at the Royal Observatory. Attendees to this summer solstice event can also take part in practical workshops showing how to make pinhole solar projectors. The event is suitable for anyone over the age of seven and is free to attend.
www.rmg.co.uk

BEHIND THE SCENES
THE SKY AT NIGHT IN JUNE

BBC Four, **14 June**, 10pm (first repeat BBC Four, **18 June**, 7.30pm)*

One of the most surprising things Rosetta discovered was the comet's duck-like shape

WHERE'S PHILAE?
Just over six months after the Rosetta comet landing, what have we learnt? *The Sky at Night* reveals the latest stunning images and results from the mission. What are the strange surface features dubbed 'Dinosaur Eggs'? Could there be weather on the comet? And of course what is the fate of the sleeping Philae lander?

**Check www.bbc.co.uk/skyatnight for subsequent repeat times*

A Brief History of Telescopes...

Wycombe Astronomical Society, Sports Hall at Woodrow High House, Amersham, Buckinghamshire, 17 June, 8pm

Astronomer Nick Howes explores the history of telescopes leading up to SKA, a project to build the largest radio telescope in the world. The talk will show how big data could be driven by astronomical research and argue that the SKA project is on the same scale as the Apollo programme. Admission is free, but non-members are encouraged to make a voluntary donation of £3.
www.wycombeastro.org

Star Formation in our Galaxy

Hertford Astronomy Group, Welwyn Garden City Golf Club, Welwyn Garden City, 10 June, 8pm

University of Hertfordshire astrophysics PhD student Carla Natário addresses the June meeting of the Hertford Astronomy Group, with a discussion on the birth and development of stars in our Galaxy. Admission is free to members and under 17s, £3.50 for non-members.
www.hertsastro.org.uk

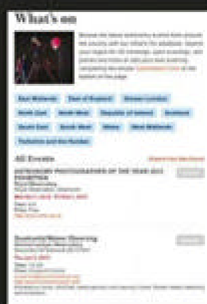
The Microwave Universe

Nottingham Astronomical Society, The British Geological Survey, Keyworth, 4 June, 7.30pm

Dr Clive Dickinson of the Jodrell Bank Centre for Astrophysics discusses the technological advances that are continuing to map the microwave Universe. In this talk he covers recent results from the Planck mission and explains what they reveal about cosmology. Admission is free.
www.nottinghamastro.org.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.



To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.

A PASSION FOR SPACE

with **Maggie Aderin-Pocock**

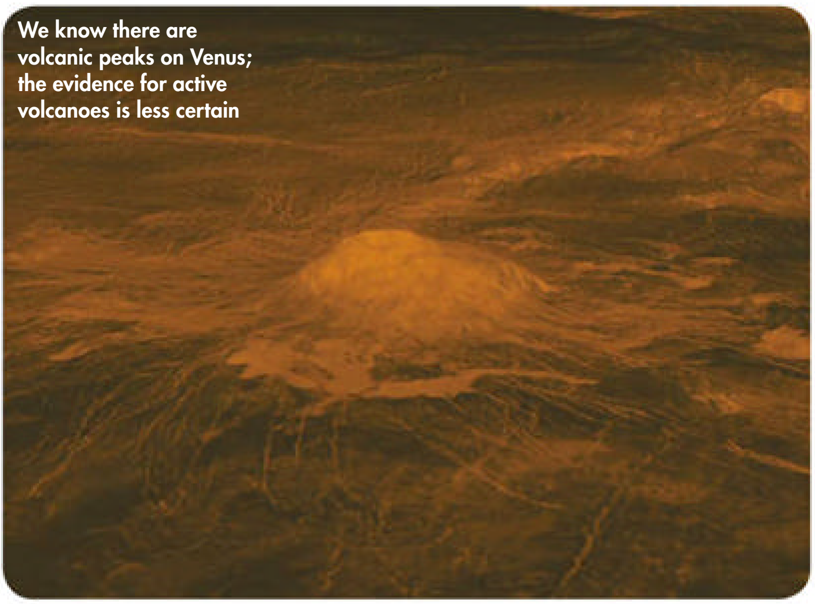
The *Sky at Night* presenter looks back at what we know about Earth's 'twin' planet, enigmatic Venus

Venus is enigmatic; the Roman goddess of love and beauty looks amazing when viewed in the night sky. It is the second brightest object out there, only surpassed by the Moon in radiance, and it truly can be considered Earth's twin, having a similar size and mass as our own planet.

It's not surprising that we set our sights on visiting it soon after the space era began. The first mission in 1961 was a failure, but in 1962 we got our first flyby with the Mariner 2 spacecraft. It revealed a planet covered with thick white clouds, which turned out to be made of sulphur dioxide.

Venus did not give up its secrets easily, and it took the Russian Venera missions of the 1970s to get to the surface. They showed us a planet with surface temperatures in excess of 450°C and light levels similar to Earth on a cloudy day. Conditions at the surface were so extreme that the Venera 8 probe only transmitted data for a mere 50 minutes and 11 seconds before succumbing to the harsh environment.

More recently, ESA's Venus Express went into orbit around the planet in April 2006 and only stopped returning data in November 2014, having been in orbit around the planet for eight years.



We know there are volcanic peaks on Venus; the evidence for active volcanoes is less certain

NASA/JPL-CALTECH/ESA

Radar mapping of the planet's surface by a previous visitor, the NASA Magellan orbiter, revealed the presence of many thousands of volcanoes, but the question of whether these were active volcanoes remained.

Finding fire

Venus Express took up the gauntlet and gathered more information on these features. Using its Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) and the Venus Monitoring Camera (VMC) it was able to observe temperature variation on the surface. Using a wavelength of 1μm that only weakly interacts with the dense atmosphere, mission scientists were able to measure transitory hot spots of kind you might associate with lava flows from an active volcano. Further evidence came from the levels of sulphur dioxide in the atmosphere. Over a period of eight years a number of elevated measurements of sulphur dioxide have been observed with increases of up to 400 per cent. This in itself does not prove that there are active volcanoes, but it is strong evidence to support the idea.

Other discoveries made by Venus Express include the finding that the planet is losing water to space due to the action of the solar wind, and that Venus's rotation is actually slowing down, with the day appearing to lengthen by 6.5 minutes over a period of 16 years.

So after numerous missions, can Venus still be considered an enigma? I think it can. Venus Express has given us a much better understanding of our sister planet, but has also thrown up many more questions that can only be answered through further missions. Venus and Earth are very similar planets that have taken two very different paths; understanding why may help us to understand our own future.

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*

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JON CULSHAW'S EXOPLANET EXCURSIONS

Jon heads to what may be the most Earth-like world we know of, Gliese 677 Cc

There's a fascinating trinary system in the constellation of Scorpius called Gliese 677, the three stars of which orbit together around a common gravitational centre. It sounds rather graceful.

I've always imagined that bodies in systems such as this would have elaborate, unusual orbits affected by many gravitational influences: orbits not just circular or elliptical, but curving, looping and doubling back along paths of beautiful complexity. It will be intriguing to get closer to the orbital clockwork of the Gliese 677 system – a country dance between celestial giants.

Steering the Perihelion to the heart of the system we're given a closer view of its stars. Gliese 677 A is the largest, a main sequence K-type star. It is a red dwarf with a rosy hue, 76 per cent of the Sun's diameter and 73 per cent of its mass. Second largest is Gliese 677 B at 69 per cent the Sun's mass. These orbit each other in a cosmological ballet.

We'll settle the Perihelion around Gliese 677 C, another red dwarf orbiting the A and B stars at a distance of 230 AU. It's only 31 per cent the mass of the Sun and is quite cute to be honest. This red dwarf has two planets confirmed around it, both in stable orbits – surprisingly for a trinary system. The innermost appears to be a 'hot Neptune' racing round its star in just seven days.

Gliese 677 Cc, the second out of the two confirmed planets, lives up to its reputation as one of the most Earth-like worlds discovered. Positioned at the warmer end of Gliese 677 C's Goldilocks zone, there's a rich, warm lushness to this planet that most humans would find delightful. The fact the planet is 3.8 times the mass of Earth gives it a surface gravity 3.8 times what we're used to; it feels oppressive at first but you do begin to adjust.

It's an astonishing terrestrial landscape in this particular spot, resembling a supersized igneous Grand Canyon. What appears to be slow flowing liquid water runs along the bottom of a valley. And this alien vista is bathed in the fireglow shades of the parent red dwarf. It's easy to imagine a partially terraformed Mars looking something like this thousands of years from now.

Seeing three stars in the daytime sky is quite marvellous. Day turns to night in a manner very different from our earthly dusks. As the parent star sets, the two more distant stars remain with a lower light intensity, like the Sun appears from the vicinity of Jupiter. This is like an odd-looking dusk and golden hour happening simultaneously; a light of such beautiful unfamiliarity.

It's impossible to stop gawping at the hybrid daylight and twilight cast on the mighty alien terrain.

There are tantalising signs of life too. At the bottom of the gorge, along the edge of the shallow water, are leathery growths of a seaweed-like vegetation. The fleshy protuberances are black in colour, perhaps to help photosynthesis or for protection against radiation from the parent star. All in all Gliese 677 Cc is a quite superb terrestrial exoplanet, adding an avalanche of greater meaning and fascination to that familiar term 'Earth like'.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

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With Martin Rees
The Astronomer Royal

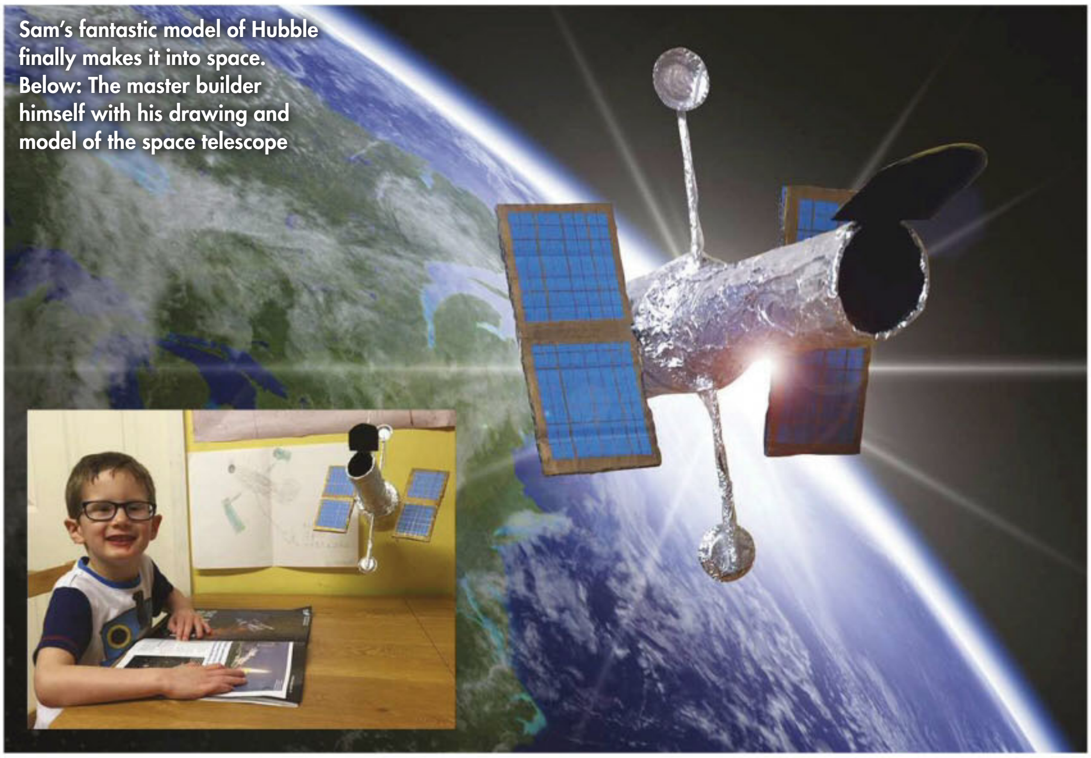
This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's. Heather Couper and Nigel Henbest's *Stargazing 2015* is a month-by-month guide to the year and you'll be able to find all the best sights with Patrick Moore's *The Night Sky*. *Stargazing with Binoculars* by Robin Scagell and David Frydman contains equipment and observing guides, and you'll be viewing planets, galaxies and more with Storm Dunlop's *Practical Astronomy*.

PHILIP'S

MESSAGE OF THE MONTH

Homemade Hubble homework



Sam's fantastic model of Hubble finally makes it into space. Below: The master builder himself with his drawing and model of the space telescope

Recently my four-year-old son Sam was tasked with a space project by his school. The task was to build a 3D space model and research his chosen topic. Sharing my interest in astronomy, he is the first one to open the wrapping on the magazine, before I get home from work! Your April edition ran a Hubble Space Telescope feature ('The Hubble Revolution', page 38) and from that he knew that he wanted to build one. First he drew it from one of the pictures he saw and then out came the kitchen rolls, crisp tube, tin foil, beer caps for antennas etc – this is the result of our efforts. Thanks again for keeping the inspiration flowing in our house. If the James Webb Space Telescope requires a companion up in space, we could send up the Sam Andrew Telescope to join it.

Andrew and Sam Andrew Copley, via email

Dear Sam, it's never too young to begin doing astronomy and you're making a great start. In 20 years' time you may have a chance to go into space yourself, and use telescopes even better than Hubble. ***– Martin Rees***

▼ **Frank (left) and Tom have truly caught the astronomy bug**

Never too late

My friend Frank is in his young eighties and has just taken up stargazing. Here he is on the left with his friend Tom, who with Frank has joined their local astronomy club. They're astounded at the technology that allows them to enjoy the night sky with apps. This pastime just has no limits!

Nicholas Cox, Swadlincote, Derbyshire

Just as Sam Andrew isn't too young to start, Frank isn't too old. By the time I reach my 'young 80s' I hope there'll be even better apps – and 3D virtual reality. ***– Martin Rees***

SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

Have your say at **twitter.com/skyatnightmag** and **facebook.com/skyatnightmagazine**

@skyatnightmag asked: What was the biggest moment for space in the past 10 years?

@ariadneassoc Has to be Philae and the Rosetta mission. Close to the Moon landing in terms of audacity and excitement.

Denise Evangelista-Scot I was so fascinated by comet ISON.

@ClydeBorn Biggest moment for space? Probably right now, because that's when the Universe had expanded the most. I'll see myself out.

Phil Heppenstall The Curiosity rover.

@ParrGordonparr The discovery of water, water everywhere.

Sue Smyth Philae and the Rosetta mission.

Are we still in the dark

I found Chris Lintott's March *Cutting Edge* ('Space's Flickering Candles', page 13) extremely interesting. The paper shows Type Ia supernovae to be fainter in galaxies where there is more star formation, rather than consistent standard candles for pinning down the rate of expansion of the Universe – the Hubble constant. However, this work was based upon studies in our local part of the Universe. If star formation rates were very much higher in galaxies in the early Universe then we may have assumed that Type Ia supernovae were brighter than they actually are when working out the Hubble constant, which led to the discovery of dark energy. Can we still be sure that dark energy exists?

David Pugh, Clacton-on-Sea, Essex

This is indeed a surprising effect. And it's indeed possible that there are evolutionary effects that aren't yet understood. But fortunately there is now quite separate evidence for cosmic acceleration, from the Planck spacecraft. ***– Martin Rees***

A relative paradox

The Standard Cosmic Model of the Universe explains that it expands equally in all directions and therefore to an observer in any place within it, it will seem as though they are at its centre. Everything observed will seem to be moving away whichever direction is being looked at.

We now know that the rate of expansion, already very fast, is actually accelerating. The most distant galaxies now observed by the Hubble Space Telescope are moving away from us at a speed that is a significant proportion of the speed of light. Observing galaxies (let's call them A and B) in opposite directions, where each of their speeds relative to us is over half the speed of light (As and Bs), raises the question of their speeds relative to each other. On the face of it, this (As + Bs) should exceed the speed of light.

It is conceivable (likely even) that there are other galaxies far beyond those in the example above, at such distances that we can never observe them, which could themselves be receding at near light speed with respect to A or B. Such galaxies 'should' therefore be moving away from each other (and us) at a rate several times that of the speed of light.

This is theoretically impossible; what is the true situation and how does it cater for the paradox?

David Tart, via email

The 'speed limit' may not apply if the clock is far from the moving object. For instance, if you are on a neutron star, distant objects could appear to move faster than light, because your clock runs slow due to the star's gravity. Distant galaxies will indeed disappear over a 'horizon' – and there are probably galaxies beyond the horizon which we can never even in principle observe. ***– Martin Rees***

We need to protect Mars

I would like to suggest that manned missions to actually land on Mars should not be the aim of current space exploration plans. There is a very good chance that there is life on Mars and if so, a manned mission would inevitably lead to cross contamination. This could be hazardous to Martian life and if anyone returned from the surface it could potentially be hazardous to life on Earth.

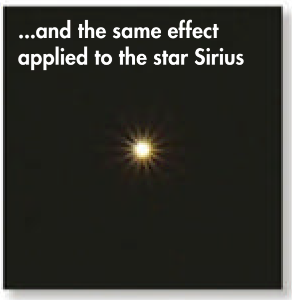
To avoid landing and any resultant contamination, we should use drone-type technology and 'telepresence' to explore multiple sites on the surface using advanced robots: the robot would be controlled at a remote location and it would feel as if the operator was actually on the surface. To this end an initial step would be setting up bases on the Moon, from which missions to the outer planets could be launched.

Glyn Burchell, Stowmarket, Suffolk

If there's life on Mars, we should avoid contaminating it, and quarantine any returning spacecraft. And even if there isn't, some may feel that Mars should be preserved, like the Antarctic, as a pristine environment. ***– Martin Rees***

Bursting with creativity

Steve's starburst shot of briliiant planet Venus...



...and the same effect applied to the star Sirius

I just wanted to thank you for your tips on photographing Venus in the April issue (*The Sky Guide*, page 60). I'm always on the lookout for new techniques to try so I was particularly interested in the starburst effect mentioned. I was also eager to try my new Sky-Watcher Star Adventurer mount, so Venus seemed like a perfect target. After some experimentation I got some pretty pleasing starburst effects. I also found that the technique worked well with Sirius too. I'll certainly be using the technique again, perhaps with Jupiter next time. It would be an interesting challenge to attempt to capture a starburst effect with the Galilean moons.

Steve Brown, Stokesley, North Yorkshire

Worth a try, but the moons may be too faint compared to Jupiter itself. You might do better with a star cluster. ***– Martin Rees***

OOPS!

In the May issue's *First Light* review of the Vixen SX2 mount, the Starbook One hand controller is said to have a Go-To database; this is not the case.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Hotshots

This month's pick of your very best astrophotos

SOLAR ECLIPSE SPECIAL
20 MARCH 2015

PHOTO OF THE MONTH

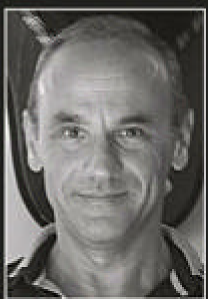
▲ Luigi Fiorentino, Bari, Italy

Luigi says: "The weather forecast for 20 March was excellent. I had set up all my equipment the day before on my roof to prevent any last-minute setbacks: my Lunt and APO in parallel on an EQ-G mount, as well as the connection rings to the cameras, batteries and computers. The sky was so clear and the visibility so good that even the hills, some 50km from my location, were clearly visible. I had no problems throughout the whole eclipse and everything turned out well."

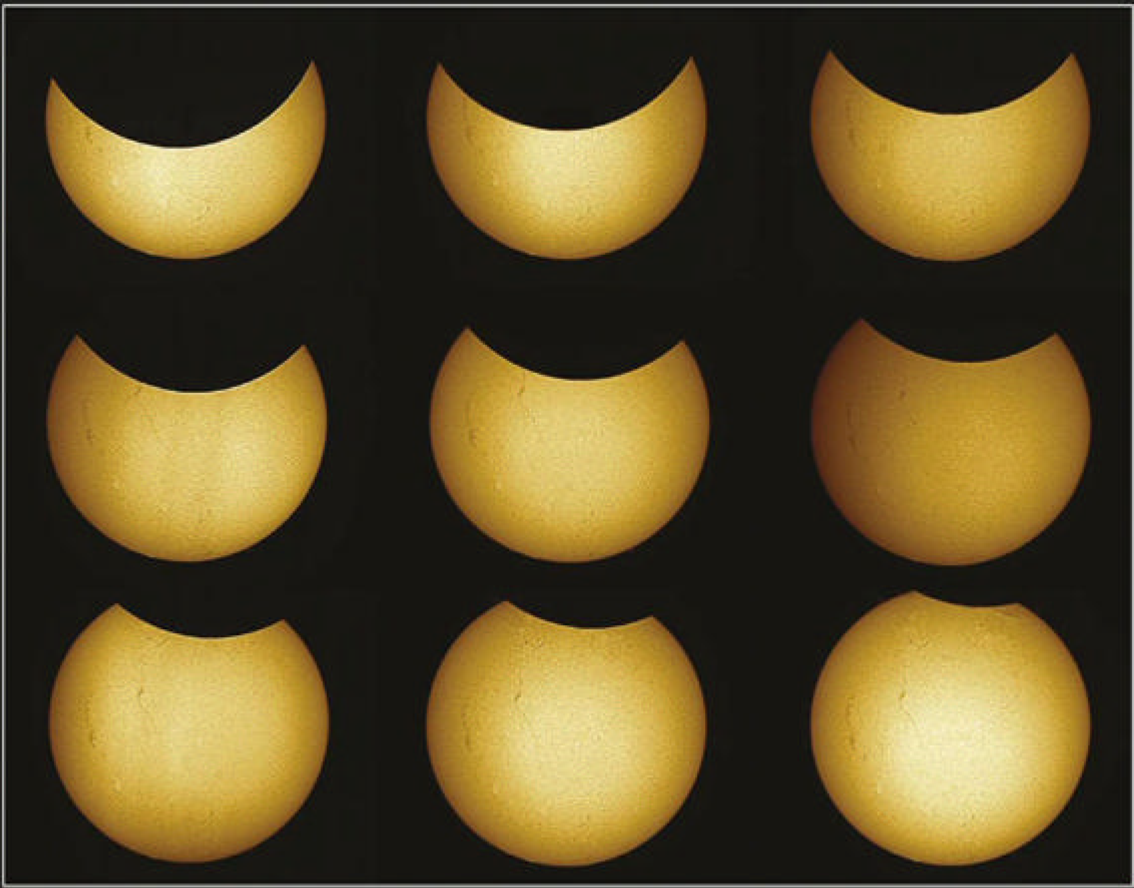
Equipment: Point Grey Chameleon 1.3 megapixel mono CCD camera, Lunt LS60THa/B1200CPT hydrogen-alpha telescope, Orion Atlas EQ-G mount.

***BBC Sky at Night Magazine* says:** "Photographing an eclipse is always a challenge and requires timing and preparation. Luigi's efforts ahead of the event clearly paid off, judging by this spectacular image shot in hydrogen-alpha light. He's really gone the extra mile to obtain a phenomenally detailed souvenir of the 2015 eclipse."

About Luigi: "I'm 49 years old and have loved astronomy since my childhood, when my



father bought me a very small Japanese telescope and I started taking pictures of the Moon and Sun. I'm the co-founder of an astronomy club in my city and mainly focus on solar imaging in hydrogen-alpha and white light, as well as astro-reportage: satellite transits and Solar System events such as comets, meteors, eclipses and aurorae."



◀ Mark Griffith, Swindon

Mark says: "This picture is a collage of nine images with five-minute intervals between them. There was thick cloud to start with and it looked as though I was not going to be able to capture any images; fortunately they started to thin. Light cloud remained for the rest of the eclipse, but with the Sun being so bright I was still able to capture some detail."

Equipment: Imaging Source DMK41 monochrome CCD camera, Lunt 35mm hydrogen-alpha telescope, Sky-Watcher NEQ6 Pro mount.

Peter Wright, Scunthorpe ▶

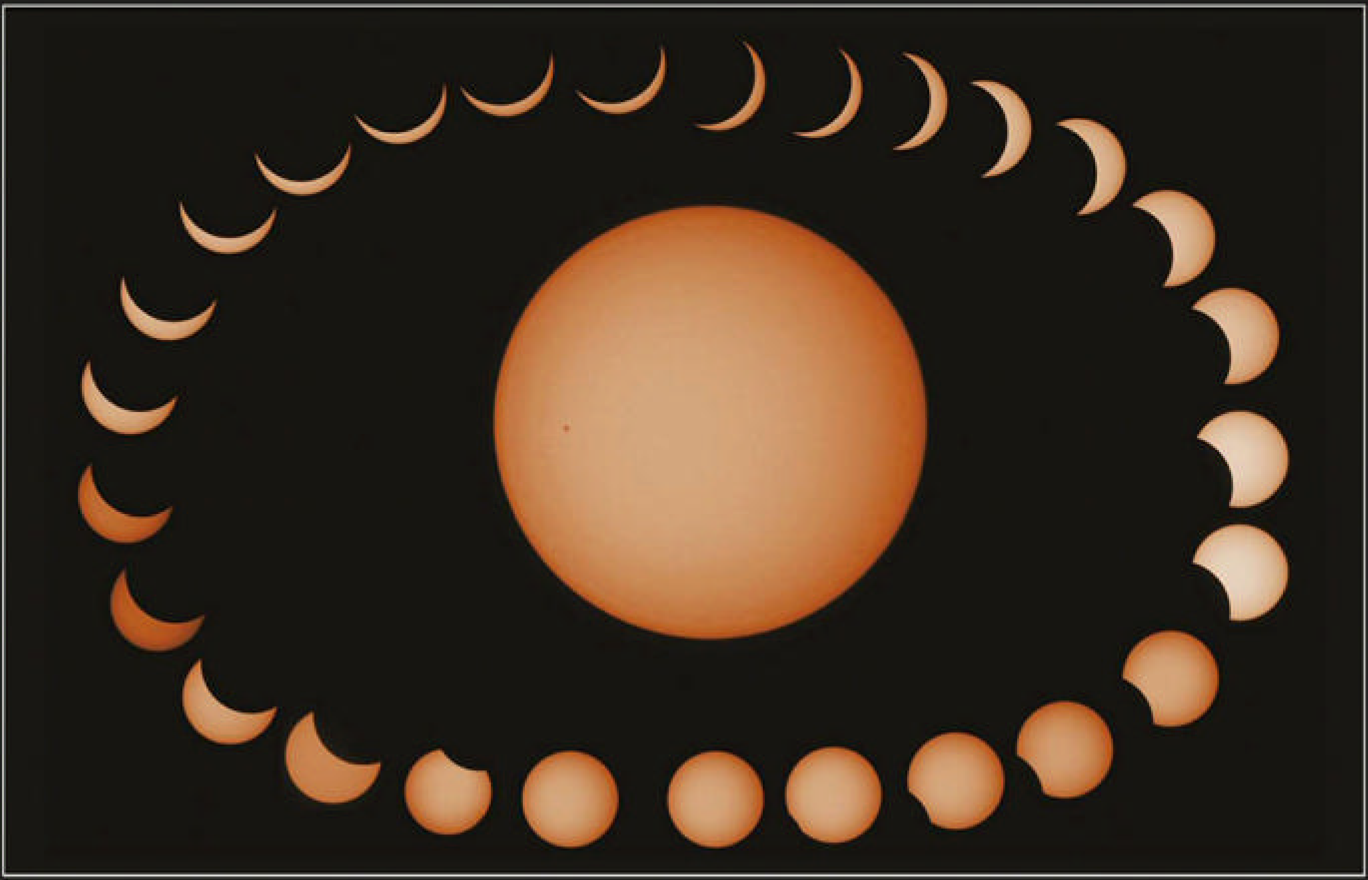
Peter says: "The sky was clear for the early part of the eclipse with some cloud approaching. By the time of near totality the sky was more or less overcast with only a few glimpses of the Sun. I managed to grab a dozen or so shots at maximum coverage through the clouds but most of them didn't show the eclipse, except for a couple after the clouds thinned. The sky then cleared (typically) and we were able to watch the rest of the eclipse through a solar filter."

Equipment: Nikon D40 DSLR camera, 18-55mm zoom lens.

▲ Leighton James, Bristol

Leighton says: "I wasn't particularly hopeful that the cloud would clear in time but thankfully it did and so I dashed to the park on my bike armed with my tripod, camera and filters. In post processing, I increased the contrast and lowered the blacks. I then overlaid the images to show the sequence of the Moon passing in front of the Sun."

Equipment: Canon EOS 5D Mk III DSLR camera, Canon 100-400mm lens, polariser filter.



▲ Chris Greenland, Cardiff

Chris says: "The image was shot in my back garden in the centre of Cardiff. The seeing conditions were excellent, with no cloud cover and just a gentle breeze. This was the first time I had tried to image the Sun and, with very basic kit and a bit of luck, it worked out ok."

Equipment: Nikon D40x DSLR camera, Sky-Watcher Explorer 150P telescope, Nikkor 50mm lens, home-made solar filter.

▲ Patryk Tomalik, Gloucester

Patryk says: "This picture was taken in my garden in Gloucester. I didn't expect a plane to be in the frame so that's why I 'm really pleased with it."

Equipment: Canon EOS 50D DSLR camera, Sky-Watcher 120ED telescope, AZ EQ6-GT mount, Baader OIII filter and Baader ND5 film.

◀ David De Cueveas, Brittany, France

David says: "It was a fantastic journey to shoot the eclipse in France. It was raining almost everywhere. I left very early in the morning to travel the three and a half hour trip along the coast in Brittany."

Equipment: Canon EOS 450D DSLR camera, Canon EF 70-200mm lens.

◀ Konstantinos Tranganidas, Perthshire

Konstantinos says: "The picture was taken at the summit of Kinnoull Hill overlooking Perth and the river Tay. It was a chilly morning, with clouds starting to appear only after the eclipse peaked. The atmosphere was great, as a large group of people had gathered to observe the event. Although I had already taken many pictures of the Moon, this was the first time I attempted imaging the Sun. My hands were absolutely frozen that morning, but it was totally worth it. I was surprised by the quality of the photos taken with the very basic equipment I used."

Equipment: Panasonic Lumix DMC-FZ72 bridge camera, Silvercrest spider tripod, home-made solar filter.

Chris Marshall, Staffordshire ▶

Chris says: "This was my first attempt at solar imaging. I had never used a Herschel wedge before and think it is a great piece of equipment for a relatively modest cost. I am now a fan of solar imaging, especially since you can do it when it's warm!"

Equipment: Point Grey Research Flea3 1.3 megapixel monochrome camera, Opticstar ED80 refractor, Celestron CGEM DX mount, Lunt Herschel wedge.

◀ Stuart Holley, Stonehaven

Stuart says: "I was really lucky with this one as the clouds meant I could get the exposure just right without any special equipment. Up until 15 minutes before the photo was taken it was too cloudy to see the eclipse so it was really good that the clouds thinned."

Equipment: Olympus SZ-14 compact camera.

ENTER TO WIN A PRIZE!

ALTAIR ASTRO

We've joined forces with Altair Astro UK to offer the person behind next month's best *Hotshots* image a fantastic prize. The winner will receive an iOptron SkyTracker camera mount, designed to keep your camera tracking at the same speed that Earth rotates. www.altairastro.com • 01263 731505

Email your pictures to us at hotshots@skyatnightmagazine.com or enter online.

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To mark 10 years of *BBC Sky at Night Magazine* we have 5 copies of our first issue to give away, featuring the inaugural coverdisc and a pull-out of Patrick Moore's 1969 Moon map.

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Tweet us (@skyatnightmag) a picture of yourself holding your favourite issue of *BBC Sky at Night Magazine* using the hashtag #SANMag10 between 15 May and 4 June. Five winners will be selected at random, each receiving a copy of issue 1!

Terms and conditions: Prize is 5x *BBC Sky at Night Magazine*, Issue 1. Promoter is Immediate Media Company Bristol Limited. Entrants must not be employees of the Promoter. The winners will be selected at random. Only one entry per person per competition. Entrants' details will be used in accordance with Immediate's Privacy Policy: http://www.immediate.co.uk/privacy-policy/. No responsibility accepted for lost, delayed, ineligible or fraudulent entries. The winners will be notified via twitter within 14 days of the close of the promotion and their names printed in the August 2015 issue. The draw is final and no correspondence will be entered into. Promoter reserves the right to substitute the prize with one of the same or greater value but there is no such cash alternative. This promotion is subject to the laws of England.

COMPETITION CLOSES 11.59PM ON 29 MAY 2015

THE NEW ERA OF SPACE EXPLORATION

We are living in a second golden age of space exploration. Missions such as NASA's Curiosity rover and ESA's Rosetta/Philae probe are proving that technologies have reached a level of advancement where ambition is becoming realisable achievement, providing the inspiration that generations of the future will thrive on.

Building on the legacy of the audacious Apollo programme, humankind now has an armada of robotic probes exploring the Solar System, extending our knowledge from our home planet to encompass the physical environment billions of kilometres away; once New Horizons meets Pluto, we will have visited every significant known body in orbit around our home star.

But what do these missions add up to, and where are they taking us? On the coming pages, Dr James Green and Prof Mark McCaughrean, senior figures in the American and European space agencies respectively, give us an exclusive outline of their organisations' visions for planetary exploration over the next two decades. They reveal the collaboration that lies behind the exacting detail required to make these epic scientific and engineering feats a success, and the justification for maintaining long-term funding of space exploration.

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THE NASA DIRECTIVE: STEPPING STONES TO MARS

Now that we've probed our nearest astronomical neighbours, the next challenge is to visit them. NASA's **James L Green** explains why we need to leave Earth and why our next destination should be Mars

NASA's Curiosity rover is currently doing what we can't yet do by hand – analysing Martian rocks to better understand the planet's geology

▾ Our exploration of other worlds began with Mariner 2's pass of Venus in 1962

ABOUT THE WRITER

Dr James L Green has been the director of NASA's Planetary Science Division since August 2006. He has worked at NASA since gaining his PhD in space physics in 1979.

A little over 50 years ago, Mariner 2 flew by Venus, becoming the first spacecraft to successfully encounter another planet. That was in December 1962. Since then the world's space agencies have mounted an impressive range of exploratory missions across the Solar System.

When the New Horizons spacecraft passes through Pluto's system this July, humankind will have completed its initial survey of the solar neighbourhood. Nearly all of our previous Solar System missions have been reconnaissance flybys, or orbiters designed to gather the most basic information about their targets. Thanks to those missions we now have a rudimentary overview of the Solar System and the dangers of the cosmos.

But the dangers aren't confined to outer space. Down here on Earth humanity's future is jeopardised by potential ecological disaster and dwindling supplies of fossil fuels. We also face the ever-present threat of asteroid strikes. As recently as the early 1960s geologists believed that the craters on the Moon were almost all volcanic. But thanks to Eugene Shoemaker and others, by the time humans first set foot on the Moon in 1969, we knew that the vast majority were impact craters. It was a truly profound realisation and we now have evidence that shows Earth, like the Moon, suffered significant asteroid impacts in the past and will continue to do so in the future. ▸

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New Horizons arrives at Pluto in July; it will give us our best glimpse of the dwarf planet yet

▸ Asteroids aren't the only threat to humanity. The Sun will continue to grow hotter and in about a billion years Earth will fall out of what we call the habitable zone that exists around it. The inescapable conclusion is that there is a limit to how long our species can inhabit this planet. As the science-fiction writer Robert Heinlein stated, "The Earth is just too small and fragile a basket for the human race to keep all its eggs in."

Leaving the hen house

We are now entering a new era of space exploration, one in which we will undertake increasingly complex missions that land, rove and return samples from the most important bodies in the Solar System. The successful landings of the Curiosity rover on Mars and ESA's Philae lander on Comet 67P/ Churyumov-Gerasimenko clearly demonstrate that space agencies have the ability to explore the Solar System with greater intensity. These missions are the start of something important. Today, our robotic scientific explorers – and the scientists and engineers behind them – are paving the way for humanity's future beyond Earth.

We are headed in the right direction because I truly believe that a single-planet species will not survive. We have to move off this planet and into the Solar System – and we are developing the capability to do just that. For humans the accessible targets in the Solar System are the Moon, asteroids and Mars, all three of which continue to be studied in detail and are prominent in future international exploration plans. But make no mistake: the next target for human exploration must be Mars.

Mars is the most Earth-like planet in the Solar System and is within the habitable zone around the Sun. It is a rich destination with absolutely spectacular vistas, resources and history. More light shed is being shed on them thanks to the scientific missions currently operating on Mars, building on the knowledge gained from the previous missions of the past 40 years.

It is widely recognised that the Curiosity rover's safe landing on Mars was a major engineering milestone, eclipsing all other landers that have been sent to the surface of the Red Planet. But it represents more than that: the rover is a scientific marvel with the

▲ Increasingly complex and ambitious missions such as Curiosity (above) and Rosetta/Philae (top right) demonstrate our growing ability to explore the Solar System; top left, shots like this from Curiosity are helping to demystify the Red Planet

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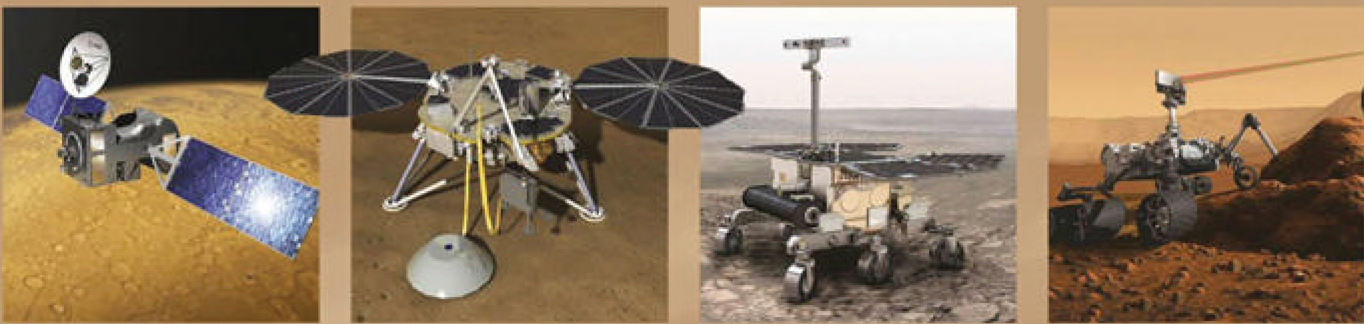
▲ If there is water trapped beneath the carbon dioxide snows of Mars's polar caps, it would make a human colony that much more feasible



▲ The quartet of future missions paving the way to Mars. From left: the Trace Gas Orbiter, InSight lander, ExoMars rover and Mars 2020 rover

most sophisticated geological instruments ever flown to another planet.

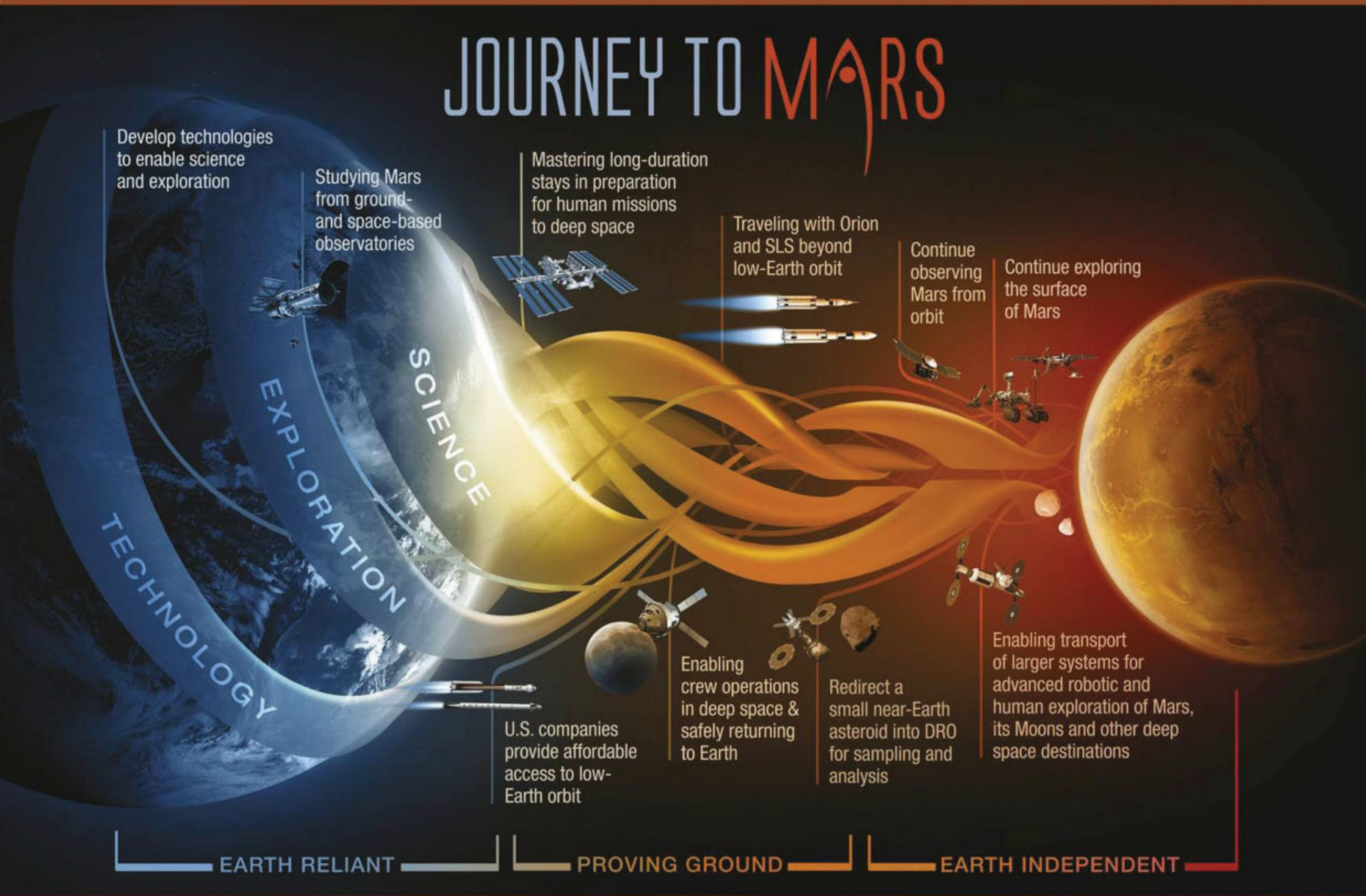
Curiosity has been on the surface for a little over one Martian year now. From the data it has sent back we know that Mars was more Earth-like in its distant past than we initially thought, with rivers, lakes and streams, a thick atmosphere with clouds and rain, and perhaps an extensive ocean. Although today Mars is rather arid, scientists now believe that there are vast amounts of water trapped under its surface and beneath the carbon dioxide snow of its polar caps. Water is the key that will enable human activity and a long-term presence on Mars.

Working towards a colony

Planetary scientists have made significant progress in understanding what Mars is like today and what it was like in the past. NASA, ESA and the Indian Space Research Organisation all have Mars exploration missions underway, and their main aim is to follow the signs of water. But it doesn't end there. Missions are already being planned for the next decade, missions that will explore the past habitability of Mars. ESA is collaborating with Russia on the ExoMars Trace Gas Orbiter, while NASA is working on the InSight lander, both set to launch in 2016. Those two will be followed by ESA's ExoMars Rover in 2018 and then NASA's Mars 2020 rover, which will both seek out signs of past life on the Red Planet.

The Mars 2020 rover will have the same architecture that Curiosity used to land on Mars, but a completely new package of instruments: tools to core and characterise the ancient Martian rocks, but also extract oxygen from Mars's carbon dioxide rich atmosphere to demonstrate an initial capability for humans to 'live off the land'. I expect more instruments will be deployed that will enable us to make use of more of the resources that exist on Mars today.

We have been preparing for our journey to Mars for many years. We now have assets that enable us to work out where humans will land on Mars in the future. We will start determining these landing sites over the coming years. Finding a suitable landing location will be an exciting ▸



process that will allow us to take the next steps towards a manned voyage to Mars.

NASA is already developing the capabilities needed to send humans to the Red Planet with the first missions set for the 2030s. But before those missions can go ahead, there are many more that need to be successfully undertaken to lay the groundwork for a manned trip.

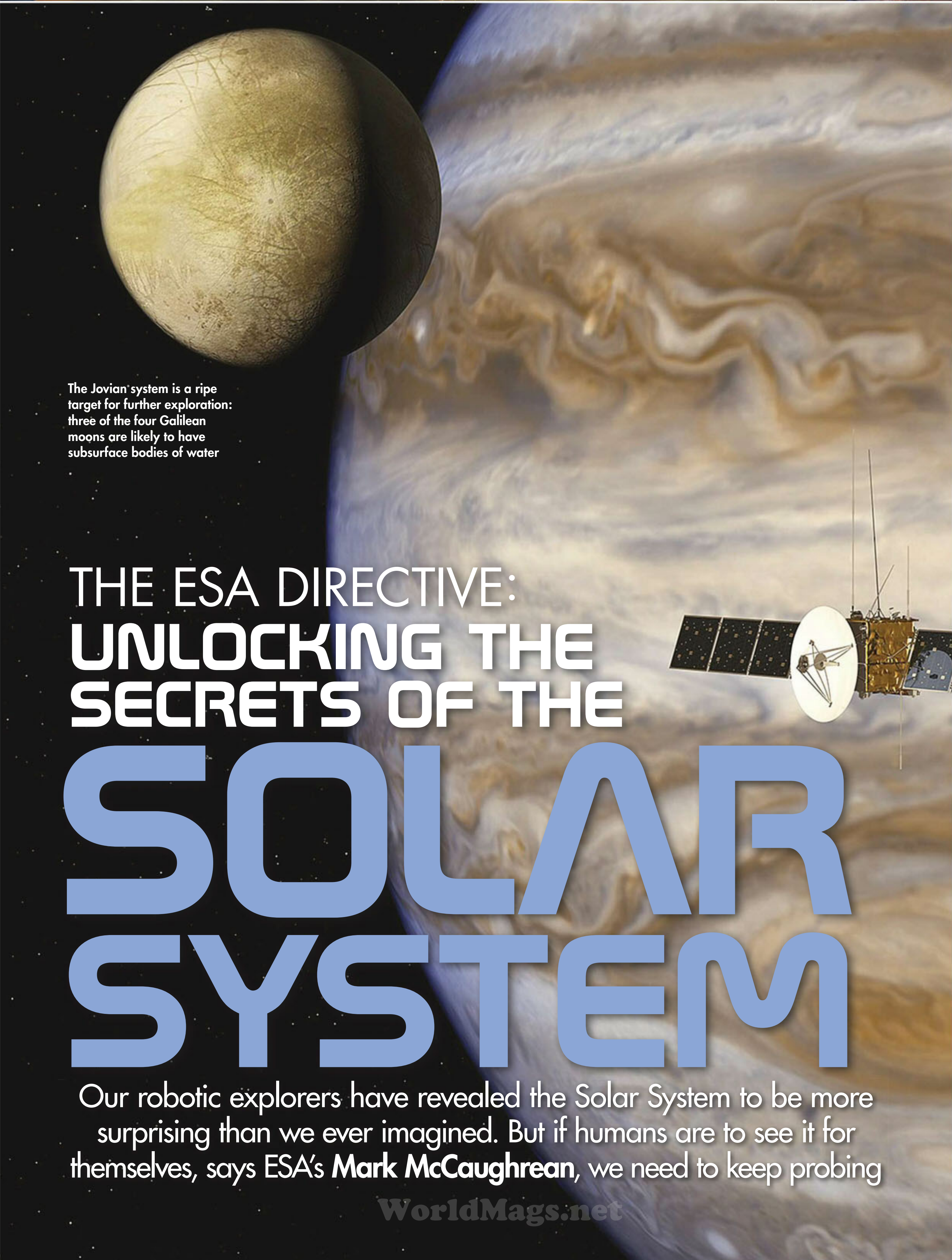
We know that there are many more challenges to overcome before human missions to Mars are possible. These challenges include finding ways to travel there safely through the harsh radiation of space, landing much more massive systems on Mars than the Curiosity rover, living and working on Mars, and how to return safely. Solving these problems over the next couple of decades and generating the funding necessary to support an international human exploration effort to Mars will ultimately determine the schedule.

But it's definitely worth the effort because it's an endeavour that will improve lives on Earth by advancing our scientific knowledge. The discoveries we will make along the way will enable us to develop new technologies that will benefit everyone and create economic opportunities, as all giant leaps in transportation and exploration have demonstrated in the past. It's these steps that will lead us from this planet to Mars and then out into the farther reaches of the Solar System. I believe the journey is worth the risks.

▲ Today's missions to the Red Planet are part of a much larger NASA scheme to establish a human presence on Mars

▼ For humans to live off the land on Mars, we must send significant infrastructure, such as habitations

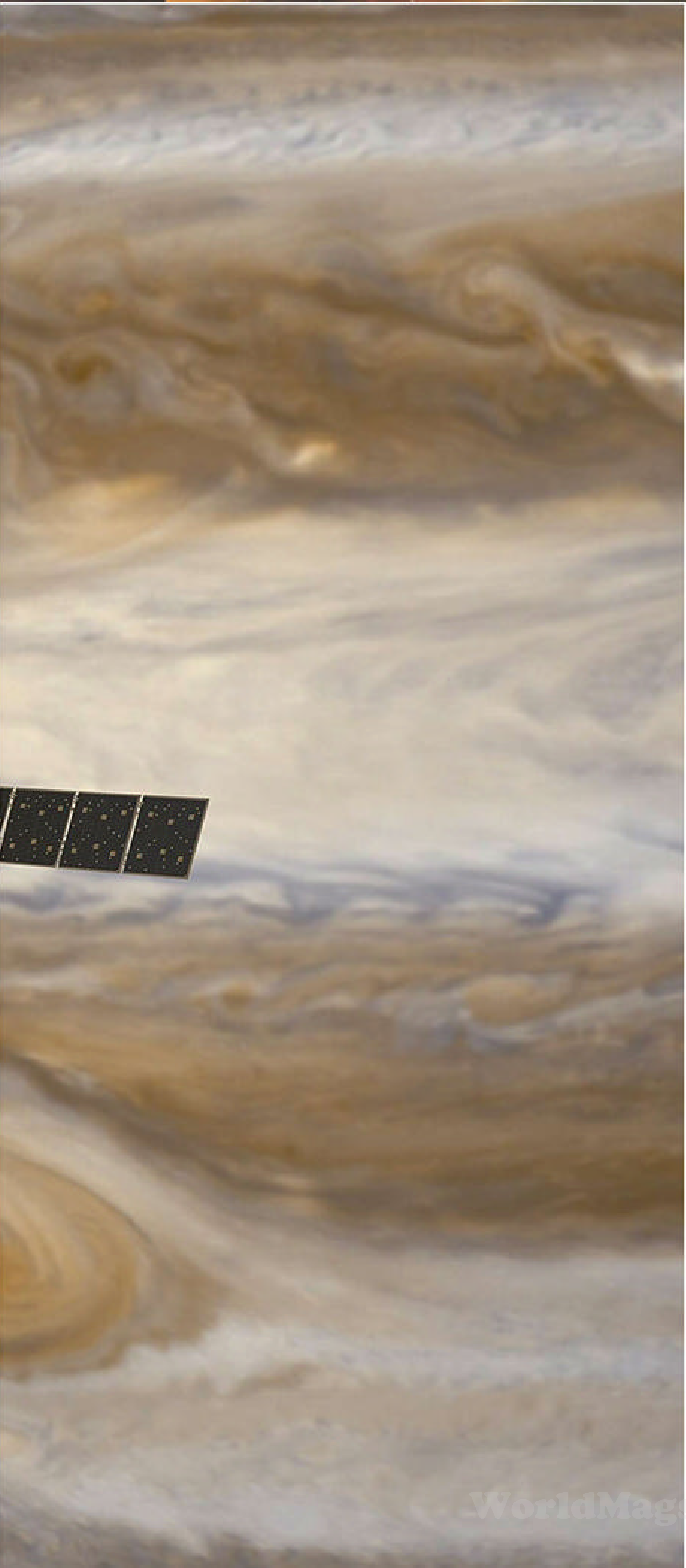
ISTOCK, NASA

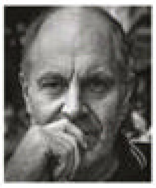


The Jovian system is a ripe target for further exploration: three of the four Galilean moons are likely to have subsurface bodies of water

THE ESA DIRECTIVE: UNLOCKING THE SECRETS OF THE SOLAR SYSTEM

Our robotic explorers have revealed the Solar System to be more surprising than we ever imagined. But if humans are to see it for themselves, says ESA's **Mark McCaughrean**, we need to keep probing





ABOUT THE WRITER

Prof Mark McCaughrean is the senior science advisor in ESA's Directorate of Science and Robotic Exploration. He is also on the Science Working Group for the JWST.

In a time when we're used to powerful ground- and space-based telescopes showing us young stars being born hundreds of lightyears away and supernovae exploding in distant galaxies billions of years in the past, we sometimes overlook quite how vast our cosmic back garden – the region of space we call the Solar System – truly is.

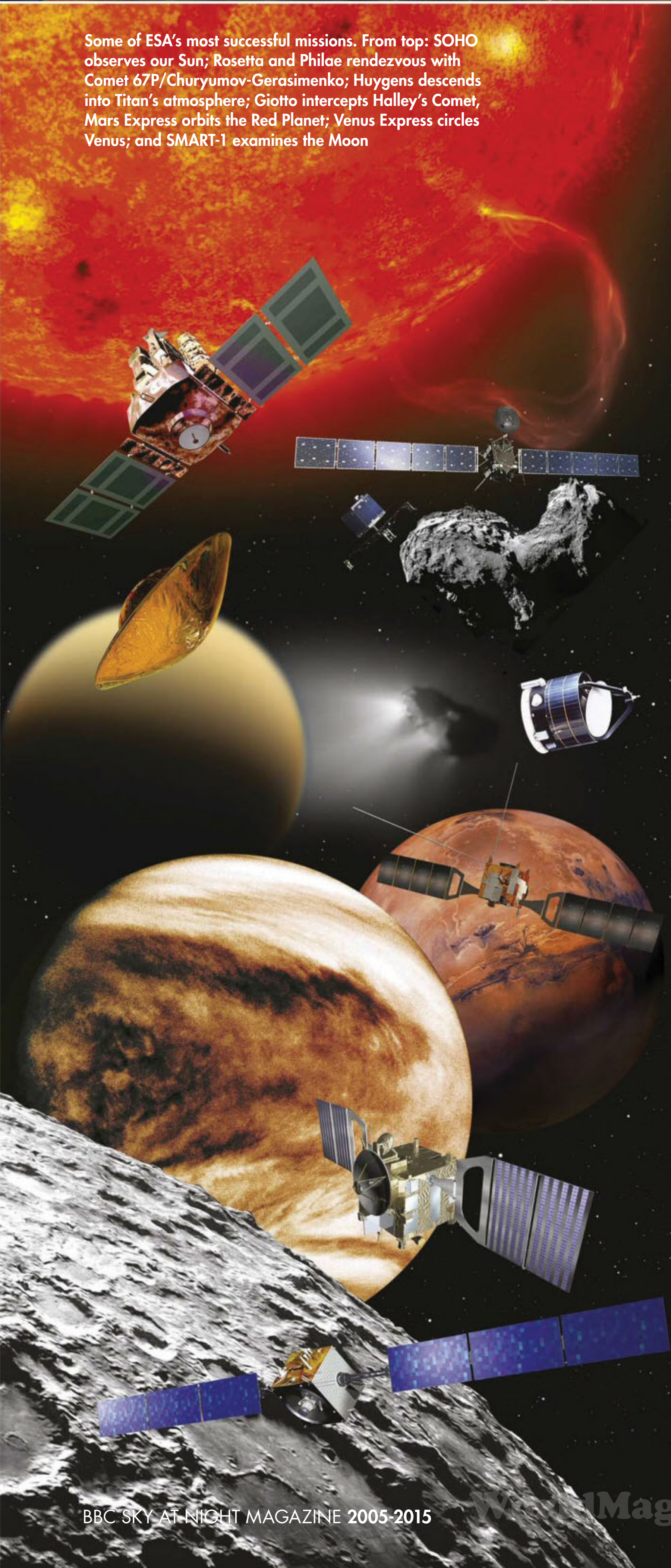
Touch the fingers and thumb of one hand against those on the other hand, and curve them to make a ball-shaped cage. Roughly speaking, the Earth would just fit inside that cage if shrunk down by a factor of 100 million. At this scale, commercial airliners would only fly the width of a human hair above the Earth's surface. Since 1972, the farthest humans have been is just a few millimetres away, the most distant orbits achieved by the various space stations that have circled Earth. Briefly, between 1968 and 1972, the Apollo astronauts bravely ventured as far as the Moon, a full 4m away in our model.

Reaching the Moon took only a few days, but travelling further is difficult and that's a key reason why it hasn't happened yet. The next natural destination is Mars, but on this scale it would be anywhere between 0.5km and 4km away, depending on where the Red Planet and Earth are in their orbits. Jupiter would be almost 8km away on average and Saturn 12km.

Nevertheless, and in spite of the great distances involved, in the past 50 years or so we have sent out robots to explore other planets, moons, comets and asteroids on our behalf. Soon, NASA's New Horizons spacecraft will reach Pluto, 75km from our model Earth. Voyager 1 has travelled farthest of all: launched in 1977, it is now in interstellar ▸

The Moon is a short hop compared to Mars, let alone the outer planets

ESA/AOES, NASA



Some of ESA's most successful missions. From top: SOHO observes our Sun; Rosetta and Philae rendezvous with Comet 67P/Churyumov-Gerasimenko; Huygens descends into Titan's atmosphere; Giotto intercepts Halley's Comet, Mars Express orbits the Red Planet; Venus Express circles Venus; and SMART-1 examines the Moon

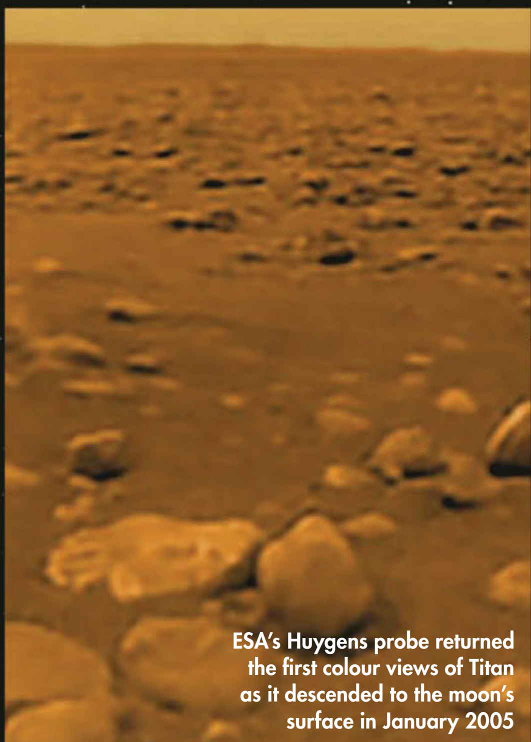
▸ space almost 20 billion km from the Earth, or 200km away in our scale model.

Following in the pioneering footsteps of the American and Soviet missions to Mercury, Venus, Mars and beyond between the 1960s and 1980s, ESA joined the grand venture to explore the Solar System in the summer of 1985 with the Giotto mission, part of an international fleet to explore the famous Comet 1P/Halley as it entered the inner Solar System for the first time in 76 years.

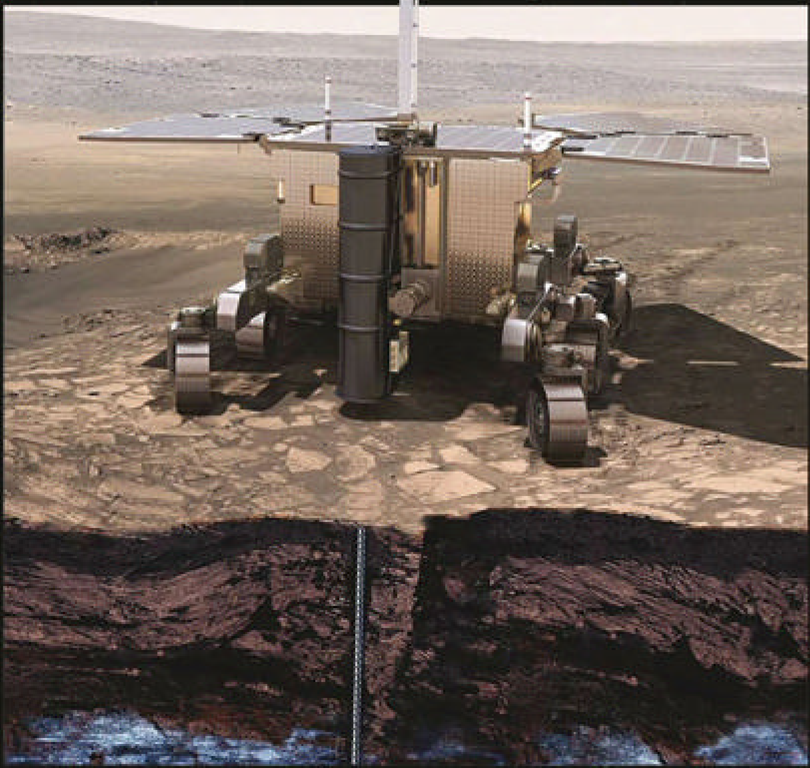
Giotto flew past the nucleus of Halley at just 596km on 13 March 1986, starting the close-up exploration of comets, the frozen treasure chests of ice, dust and organic molecules locked up since the formation of the Solar System. Giotto later encountered Comet 26P/Grigg-Skjellerup in 1992, and after a series of NASA missions to other comets, ESA's Rosetta mission famously arrived at Comet 67P/Churyumov-Gerasimenko in August 2014, deploying the Philae lander to its surface in November.

A history of discovery

In between these two missions, ESA sent the successful SMART-1 satellite to the Moon, the Mars Express and Venus Express missions to their eponymous planets, and accompanied NASA's Cassini mission to Saturn before the European Huygens probe landed on the mysterious moon Titan in 2005. Larger than the planet Mercury, Titan has a dense atmosphere of hydrocarbons, which form rivers and lakes as they rain down onto the surface. Beneath that surface is a water-ice shell and likely a deep water ocean, as have also been discovered at other moons in the Saturn and Jupiter systems.



ESA's Huygens probe returned the first colour views of Titan as it descended to the moon's surface in January 2005



▲ ExoMars 2018 will drill into the Red Planet to look for life past or present

And we should not forget the Sun itself: the ESA-NASA SOHO mission has been observing the Sun almost continuously from the first Lagrangian point for almost 19 years, joined more recently by ESA's PROBA-2. The ESA-NASA Ulysses mission studied the heliosphere, the bubble of charged particles expanding away from the Sun, for almost 19 years after its launch in 1990, while the complex interaction of the solar wind with the Earth's magnetosphere has been traced by the four Cluster spacecraft since 2000.

But returning to comets, the long wait of almost 30 years between Giotto's flyby of Halley and Rosetta's arrival at 67P/Churyumov-Gerasimenko serves to illustrate one of the challenges facing modern Solar System explorers. Many of the early spacecraft, including the Voyager twins sent to the outer planets, took rapid trajectories and flew past their targets at high speed. Voyager 1 took just 18 months to reach Jupiter and three years to reach Saturn, while Voyager 2 flew past Neptune just 12 years after launch.

Later missions have been designed to stop and explore their targets in greater detail, entering their orbits and perhaps even landing. To match orbits with those of their targets, many missions have needed to take much more circuitous routes involving multiple gravity assist flybys. Thus, Galileo took six years to enter orbit around Jupiter and Cassini-Huygens took seven to reach Saturn. And while Giotto took less than nine months to intercept Halley's trajectory as the comet whizzed past, Rosetta needed 10 years, three flybys of the Earth, and one of Mars to rendezvous with 67P/Churyumov-Gerasimenko, to match the elliptical orbit that extends beyond the orbit of Jupiter at its furthest point from the Sun and between Mars and Earth at its closest.

Not daunted by these timescales and the complex technological challenges involved, however, ESA and its partners are building a new series of Solar System explorers to delve deeper into some of the lingering mysteries of our planetary system.

A future of endeavour

The next ESA planetary mission to launch will be ExoMars 2016, in cooperation with the Russian space agency, Roscosmos. ExoMars 2016 involves the Trace Gas Orbiter, which will image the surface of Mars from above and conduct a sensitive survey of rare atmospheric gases. A key one is methane, first discovered by Mars Express: it may betray the presence of microbial life below the surface of the planet.

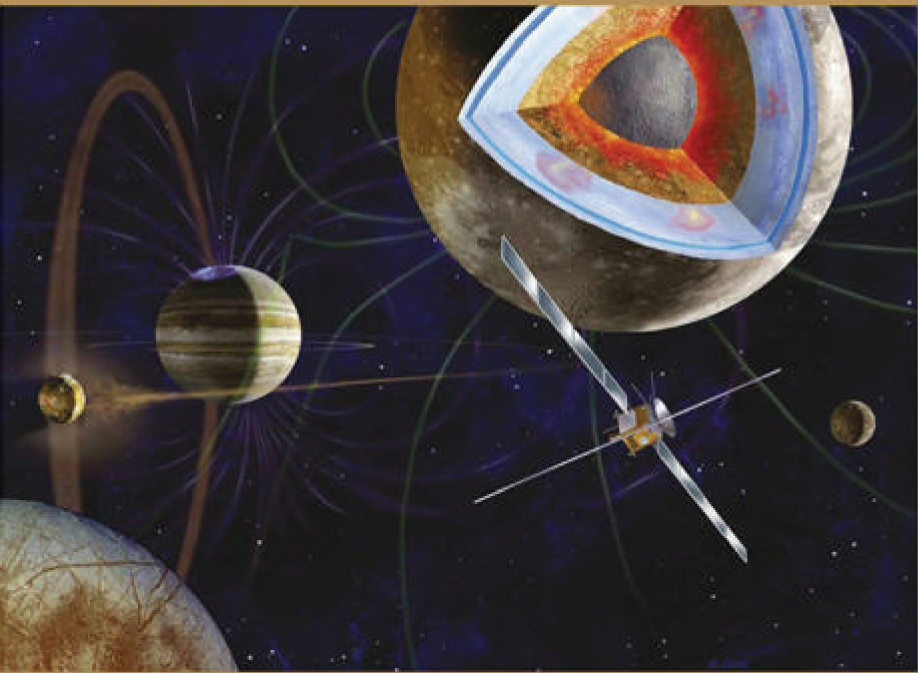
ExoMars 2016 will also deploy a demonstrator lander to the surface to help refine the entry, descent and landing systems needed for the following mission, ExoMars 2018, another collaboration with Roscosmos. This latter mission will put a 300kg rover onto the surface, including a drill to penetrate up to 2m below the surface in search of signs of extant or extinct life. The Russian platform carrying the rover will also conduct long-term scientific experiments on the Martian surface.

The innermost planet Mercury, first explored by NASA's Mariner 10 in the early 1970s and most recently by its Messenger mission, also remains enigmatic. Despite its very high temperatures, being only 50 million km or so from the Sun, it has ice caps below its insulating regolith. And even though it is small in size, it has an iron core and a significant global magnetic field.

How did Mercury come to have these peculiar properties and what can they teach us about the origin of our planetary system? This is what the BepiColombo mission hopes to find out. It is due to launch in 2017 and involves both a European polar orbiter and an independent Japanese magnetospheric orbiter. BepiColombo will take seven years to reach Mercury, using its highly efficient ion engines and a series of gravity assists of Earth, Venus and Mercury itself to slow down ▸

▼ Due for launch in 2017, BepiColombo will try to uncover the answers to Mercury's great riddles

ESA/NASA/JPL/UNIVERSITY OF ARIZONA, ESA - AOES MEDIALAB, ESA



▲ JUICE will examine Jupiter's moons in a series of flybys, hopefully revealing whether any could support life

▸ as it falls towards the Sun, enabling it to enter an orbit around the innermost planet.

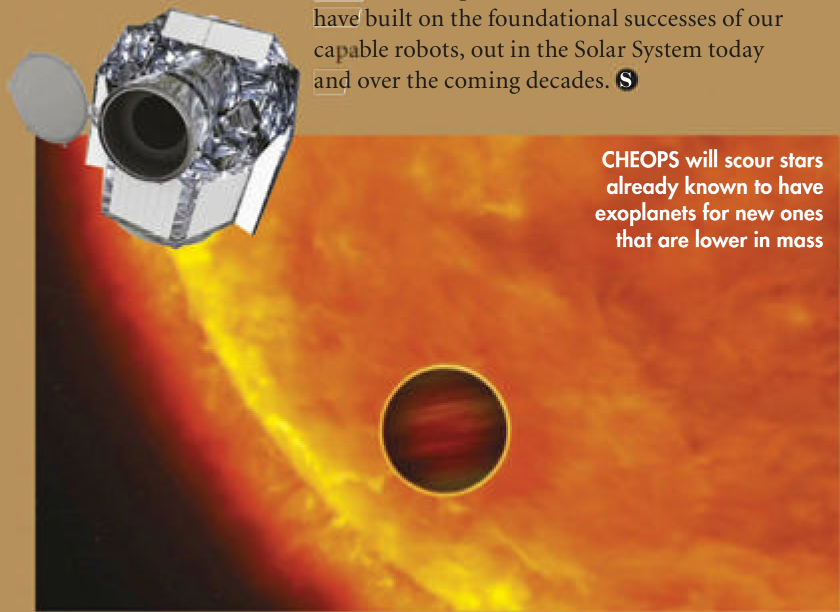
The technologies developed to cope with the extreme environment encountered at Mercury will also be used by Solar Orbiter, an ESA-led mission with strong NASA participation, to investigate how our local star creates and controls the heliosphere. After launch in 2018, gravity assists at Earth and Venus will be used over three and a half years to help Solar Orbiter reach its elliptical orbit, sampling the heliosphere in as close as just 42 million km from the Sun. Further flybys of Venus will be used to increase the orbital inclination to 25° or higher, so that the spacecraft can image and study the Sun's polar regions in detail for the first time.

In 2022, ESA will launch its JUICE mission on a seven and a half year journey involving yet more Earth and Venus gravity assists towards the Jupiter system. After the flybys by Voyager 1 and 2, the system-wide survey by Galileo and the study of Jupiter itself by NASA's currently en-route Juno mission, JUICE will focus on the icy moons of the giant planet: Ganymede, Callisto, and Europa.

Beneath their icy crusts, each of these moons is thought to harbour huge oceans hundreds of kilometres deep. JUICE will investigate the surface and internal properties of each via a series of flybys, before entering orbit around Ganymede, the largest moon in the Solar System. A key question that JUICE will hope to address is whether these deep water oceans could provide suitable habitats for life, perhaps fuelled by hydrothermal vents at a water/crust boundary.

Several upcoming missions will provide new insights into the existence of habitable worlds elsewhere, and ultimately whether or not there could be life on them. CHEOPS, aimed for launch in 2017, will study known exoplanet systems to determine their properties and search for new, lower-mass planets in the same systems. In 2024, the PLATO mission will start its survey of a large number of relatively nearby stars in search of Earth-mass planets orbiting in their habitable zones. In between, detailed measurements of exoplanet atmospheres will be carried out as part of the broad scientific remit of the powerful NASA-ESA-CSA James Webb Space Telescope, due to launch in 2018.

Although the Solar System is indeed vast, ESA and its partners continue to search for answers about the evolution of our planetary system and clues perhaps to our own origins. And if one day humans do stand under the pink skies of Mars, construct habitats on Titan, or extract the resources locked up in asteroids and comets to fuel further exploration, it will be because we have built on the foundational successes of our capable robots, out in the Solar System today and over the coming decades. S



CHEOPS will scour stars already known to have exoplanets for new ones that are lower in mass

We hope to have humans on Mars in the 2030s; how long before we might consider sending astronauts to Titan?

ESA, NASA/ESA AND G. BACON, ESA - C. CARREAU, DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY

The Sky Guide June

PLUS

Stephen Tonkin's

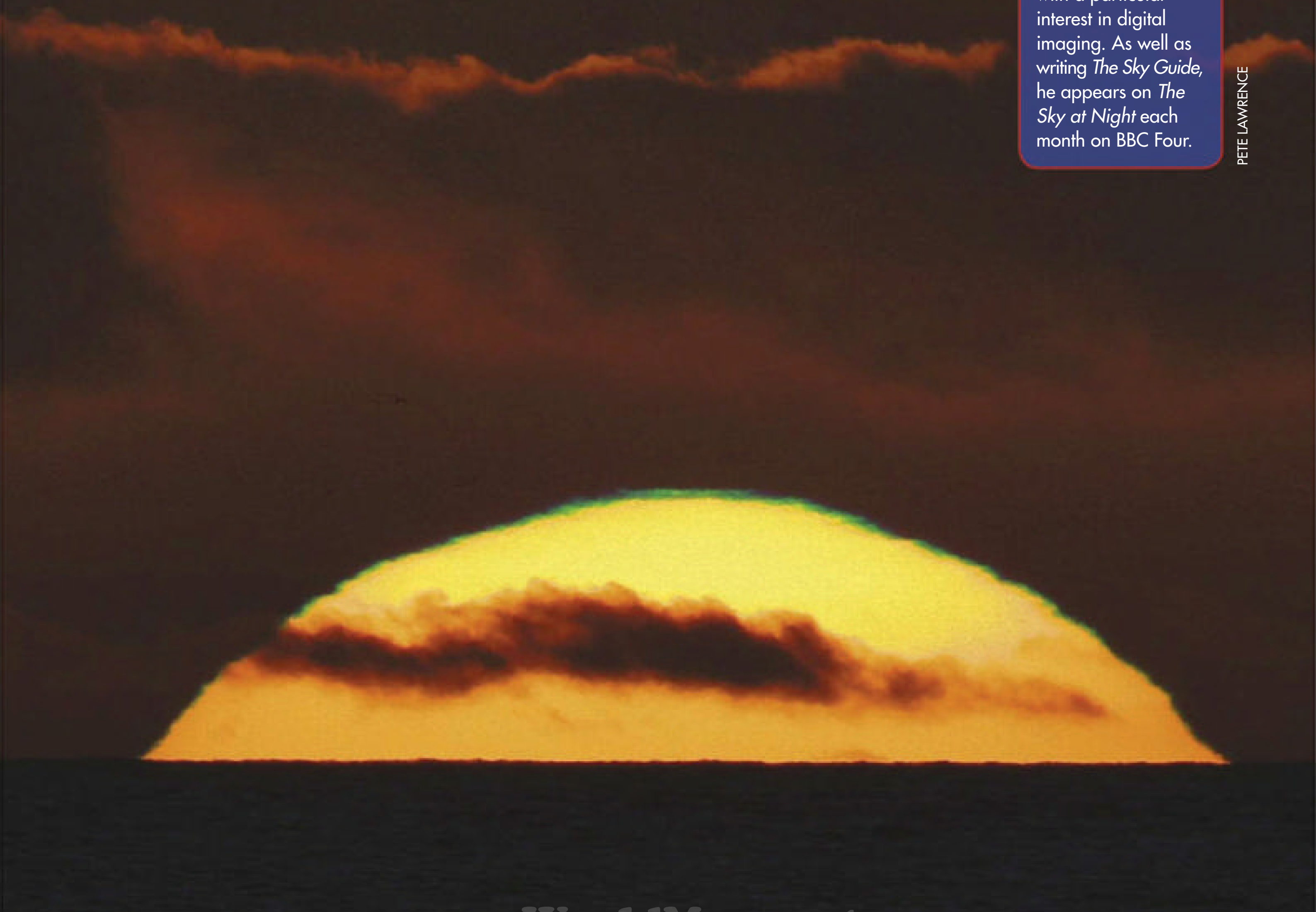
BINOCULAR TOUR

Turn to page 58 for six of this month's best binocular sights

Atmospheric effects caused by bright sunlight can be dramatic in June and this is a great time to look out for the sunrise and sunset phenomenon known as a Green Rim. If you're really lucky, it may even appear to detach from the solar disc, leading to a rare and elusive Green Flash.

Written by Pete Lawrence

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.



PETE LAWRENCE

Highlights

Your guide to the night sky this month

This icon indicates a good photo opportunity

1 MONDAY

Saturn lies below-right of the 99%-lit waxing gibbous Moon this evening. Look for them towards the southeast shortly after sunset.

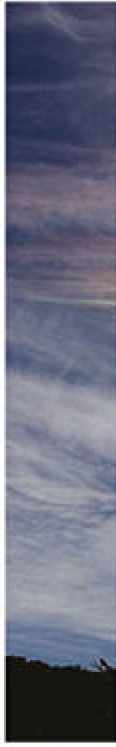
Venus currently sits in line with the stars Castor and Pollux, mag. +1.9 Alpha (α) and mag. +1.2 Beta (β) Geminorum.

2 TUESDAY

The Moon's libration favours southern limb features for the first week of June.

3 WEDNESDAY ▶

From now until the early part of July, the Sun gets high enough in the sky to create an infrequent atmospheric phenomenon known as a circumhorizontal arc. This looks like a spectrum of colour in hazy cloud, running parallel with the horizon.



5 FRIDAY ▶

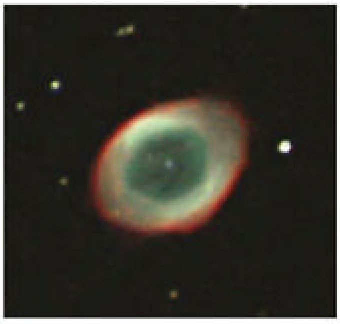
It's noctilucent cloud season once again, so keep your eyes peeled low in the northwest 90-120 minutes after sunset and low in the northeast a similar time before sunrise to see whether you can spot these amazing, high-altitude clouds. See page 51.

10 WEDNESDAY

The first peak of the Ophiuchid meteor shower occurs tonight; there's a second peak on 20 June. Both show activity with a zenithal hourly rate of around five meteors per hour and the low altitude of the radiant favours more southerly latitudes.

12 FRIDAY

Look at Venus with binoculars around midnight and see if you can pick out the faint Beehive Cluster, M44, in the background. The planet is low in the west-northwest and appears to pass in front of the cluster tonight and tomorrow night.



14 ◀ SUNDAY

The Ring Nebula, M57 in Lyra, hits its highest point in the sky around 02:00 BST (01:00 UT). It is one of the must-see sights of summer. Find it just over one-third of the way from mag. +3.5 Sheliak (Beta (β) Lyrae) towards mag. +3.3 Sulafat (Gamma (γ) Lyrae).

17 WEDNESDAY

The absence of the Moon makes this a good time to attempt our *Deep-sky tour*. See page 56.

20 SATURDAY

The darkening evening twilight will reveal the lovely sight of mag. –4.3 Venus, mag. –1.7 Jupiter and a slender 18%-lit waxing crescent Moon low in the west-northwest. The bright star off to the upper left of the trio is mag. +1.4 Regulus (Alpha (α) Leonis).

21 SUNDAY

The Sun reaches its highest point in the sky at 17:38 BST (16:38 UT) marking a point in time known as the June solstice. After this, the Sun will slowly begin its southward journey once again, towards the December solstice that occurs on 21 December.

28 SUNDAY

An 88%-lit waxing gibbous Moon can be seen close to Saturn after sunset. The Moon will lie just over 1° northwest of Saturn as both begin to set at around 02:30 BST (01:30 UT).

29 MONDAY

The fuller phases of the Moon occur when it is in a low part of the sky during the summer months. With a low altitude, this is a great time of year to look out for the so-called 'Moon illusion', which makes the Moon appear artificially larger than it actually is.

PETE LAWRENCE X 6

What the team will be observing in June

Pete Lawrence "The Venus-Jupiter conjunction at the end of the month should be spectacular so I'll be out trying to grab a photo or two. Some good opportunities arise with the Moon nearby around the 20th too."

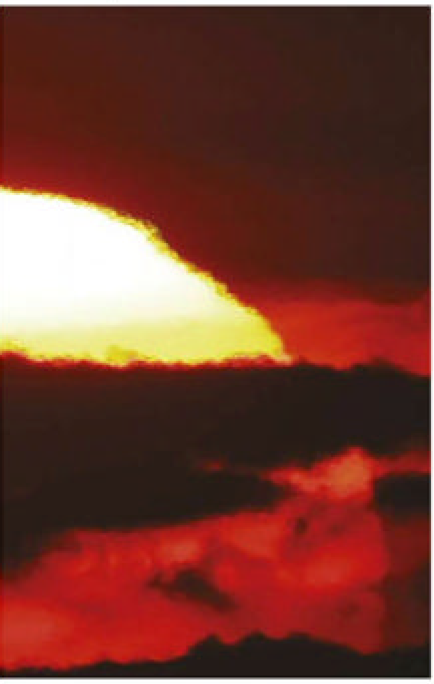
Chris Bramley "On the night of the 11th, you'll find me stretched out on a sunlounger looking towards the zenith, watching for Lyrid meteors. This year there is a great opportunity to monitor activity"

Stephen Tonkin "I shall regularly be looking north, hoping to catch sight of the ethereal electric-blue and silver shimmer of noctilucent clouds."

6 SATURDAY ▶
Venus reaches greatest eastern elongation, being separated from the Sun by 45° in the evening sky. See page 52 to learn why the planet's observed phase at this time may not be quite what you should expect.

15 MONDAY
The June Lyrids meteor shower reaches its peak tonight. Does the shower still exist? Conditions this year are optimal so turn to page 51 for details.

16 TUESDAY
The Moon is now out of the way. Despite the sky never getting truly dark during June, this is a good time to look out for star clusters such as M11, also known as the Wild Duck Cluster, or the multitude of globulars that pepper the constellation of Sagittarius.



24 WEDNESDAY
Mercury reaches its greatest western elongation of 22°. Despite this, the planet's position in the morning sky makes it quite tricky to spot. Turn to page 53 for more details.

30 TUESDAY
Venus and Jupiter are just 21 arcminutes apart this evening, visible low in the west after sunset, and heading for the west-northwest horizon. See page 50.

Need to know

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object lies on the celestial 'globe'.

HOW TO TELL WHAT EQUIPMENT YOU'LL NEED

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

BINOCULARS
10x50 recommended

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

SMALL/MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

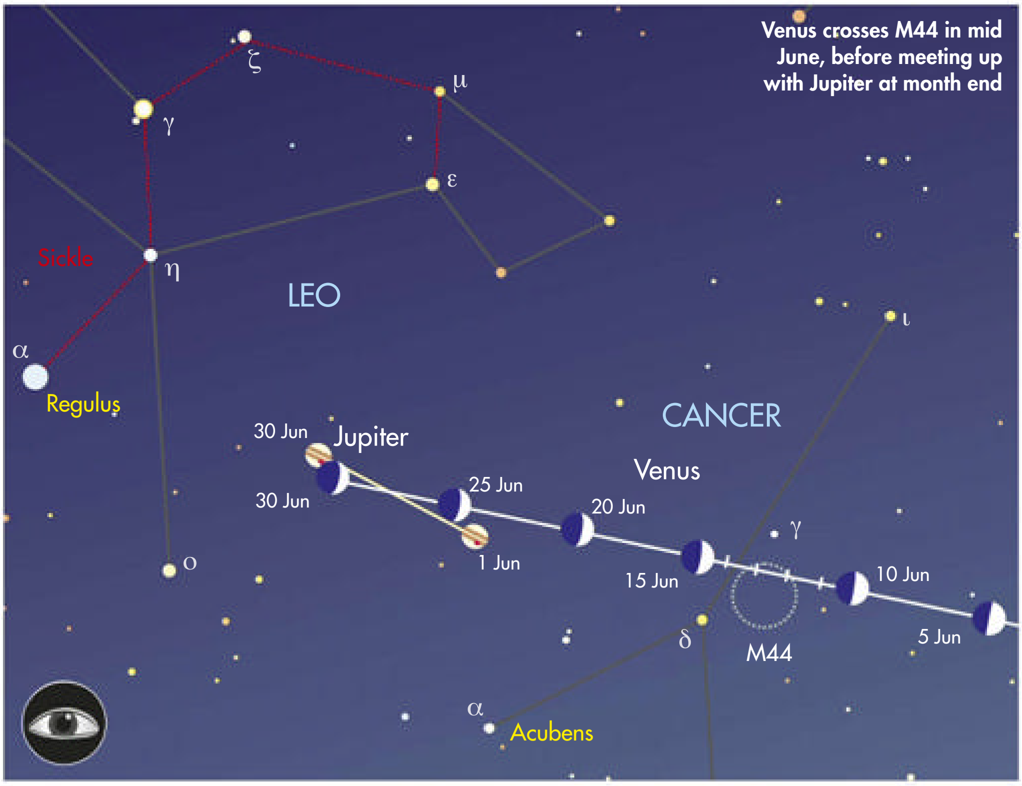
Getting started in astronomy

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing your first scope.

DON'T MISS… 3 top sights

Venus and Jupiter in conjunction

WHEN: 30 June at 22:30 BST (21:30 UT) for the close conjunction



Venus crosses M44 in mid June, before meeting up with Jupiter at month end

BOTH VENUS AND Jupiter have been dominant sights in our evening skies for some months. Jupiter has been located between Leo and Cancer for a while, lying on the line joining the Beehive Cluster, designated M44, to mag. +1.4 star Regulus (Alpha (α) Leonis). At around mag. –2.0, Jupiter has been, and remains, easy to spot.

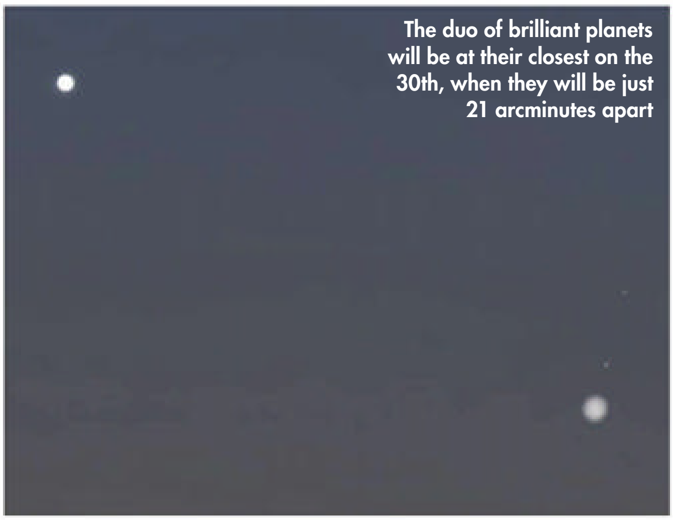
Venus is even brighter, shining away at mag. –4.2. It has been moving slowly but surely eastwards towards Jupiter from the west, and at the start of June is located close to the eastern arm of the twin Pollux in the constellation of Gemini. On 1-2 June, Venus is in line with the stars Castor and Pollux, mag. +1.9 Alpha (α) and mag. +1.2 Beta (β) Geminorum. On 1 June, looking at Venus through a telescope will show it to be 22 arcseconds across with a 52% gibbous phase. Jupiter is even bigger at 34 arcseconds and is almost fully illuminated. From 11-14 June, Venus passes very close to the Beehive Cluster, but the bright June twilight will probably make spotting the cluster stars very hard. Venus passes in front of the cluster's northern edge on 12-13 June and at this time will have grown in apparent size to 25 arcseconds across. It'll also have a reduced 44% phase.

On the evening of 13 June, mag. +1.4 Regulus, mag. –1.7 Jupiter and mag. –4.2 Venus form a straight line, with all three equidistantly spaced along it – Regulus to the east and Venus to the west.

The crescent Moon joins the scene on the 18th, but is better positioned on the 19th and 20th. On the 19th, the 11%-lit lunar crescent lies 8.5° below and right of Venus and is itself separated from Jupiter by around 7°. On the 20th, Jupiter, Venus and the Moon form a right-angled triangle, with Jupiter at the right angle. The 18%-lit crescent Moon should be fairly easy to spot at 22:30 BST (21:30 UT).

On 20 June, Venus is a 41%-lit crescent and 28 arcseconds across. The summer solstice occurs on 21 June at 17:38 BST (16:38 UT), and this is the time when night is at its shortest for the entire year. On 30 June, Venus and Jupiter are separated by just 21 arcminutes; two-thirds the apparent diameter of the Moon. Both planets will have the same 32-arcsecond apparent diameter at this time. Jupiter's full disc will contrast nicely with the lovely 34%-lit crescent of Venus. These two planets will dominate the sky, low to the west-northwest, from around 22:30 BST (21:30 UT) until they set around an hour later.

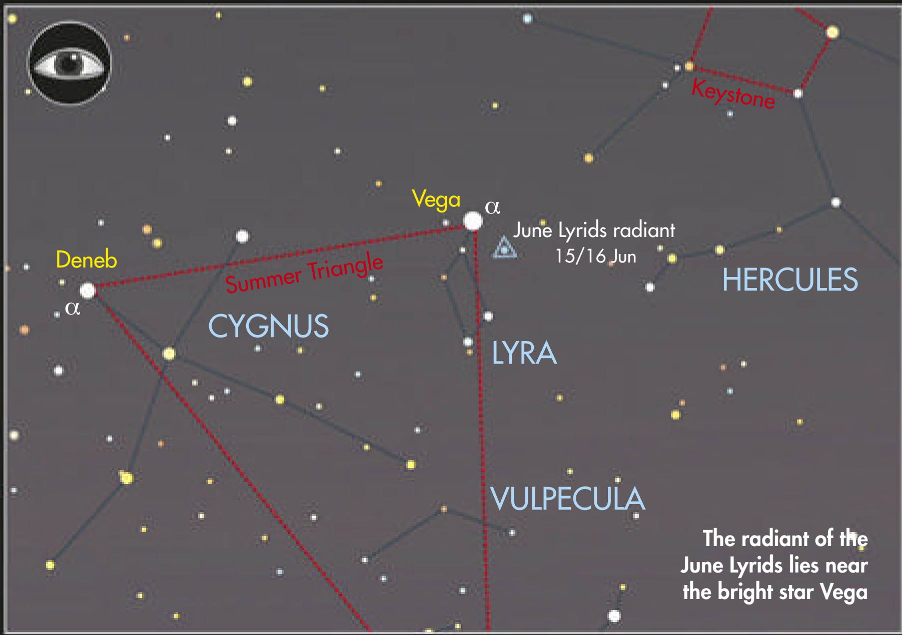
> **NEED TO KNOW**
> An object's brightness is given by its magnitude. The lower the number, the brighter the object: with the naked eye you can see down to mag. +6.0.


The duo of brilliant planets will be at their closest on the 30th, when they will be just 21 arcminutes apart

PETE LAWRENCE X4

June Lyrids: a lost shower?

WHEN: June 11-21, all night



The radiant of the June Lyrids lies near the bright star Vega

THE JUNE LYRID meteor shower reaches its peak on the night of 15/16 June with a zenithal hourly rate (ZHR) of eight meteors per hour. While this may not sound that exciting, especially compared to the giddy ZHR rates of the Perseids (80-100 meteors per hour) or the Gemids (120-plus meteors per hour), this year's shower does coincide with a new Moon period, which is a bonus.

Meteor showers that occur from May through to September tend to be popular among observers because the nights are relatively warm – just ask someone who has braved the Geminid or Ursid showers on a freezing December's evening! Another benefit of this shower is the radiant position – that's the location in the sky where the meteors appear to emanate from – because it reaches a height of 75°. A high altitude helps keep the visual rate close to the quoted ZHR value.

But there is a catch. The activity of the June Lyrids was high in the late 1960s, but rapidly declined thereafter. ZHRs dropped to around two meteors an hour during the mid 1970s. This may have been due to Earth having passed completely through the debris stream that formed the shower. Activity increased again in 1996, but then fell off considerably.

In modern times, there has been little interest in this shower. But, as the new Moon occurs on 16 June, this year presents a perfect opportunity to discover whether it's still in existence or not. So if the skies are clear between the 11th and 21st, why not contribute to meteor science by recording whether the June Lyrid meteor shower still exists or not? The night is short so observing from dusk until dawn isn't too arduous. If a trail appears to come from the radiant position marked on our chart, the meteor may well be an elusive June Lyrid.

Noctilucent cloud season is in full swing

WHEN: All month, 90-120 minutes after sunset low in northwest, or a similar time before sunrise low in northeast

DESPITE THE SHORT nights that occur at this time of year, there are still plenty of interesting things to see. One popular summer target are noctilucent or 'night shining' clouds (NLCs), which are only visible from mid to high latitudes in the northern hemisphere between late May and early August.

NLCs can usually be seen when the Sun is between 6° and 16° below the horizon. At this altitude, the sky is relatively dark but the 76-85km high layer of ice crystals that form the clouds can still reflect sunlight. It's this property that reveals their presence. The tiny ice crystals that make up the clouds are believed to form around the dust fragments left behind after meteors vaporise in the atmosphere.


NLCs are most frequently seen in the hours after sunset or before sunrise

Look for NLCs 90-120 minutes after sunset low in the northwest, or a similar period before sunrise low in the northeast. A bright display may persist all night long, slowly moving from the northwest, through north and then into the northeast.

These clouds are a popular photographic target. Their typically electric blue colour and often expansive, web-like appearance makes them excellent subjects for a wide-angle lens. The camera ideally needs to be mounted on a tripod and set to a mid to high ISO setting, between 400 and 1600. Open the lens wide and experiment with exposures of around one second, adjusting as appropriate to achieve a good result.

NEED TO KNOW

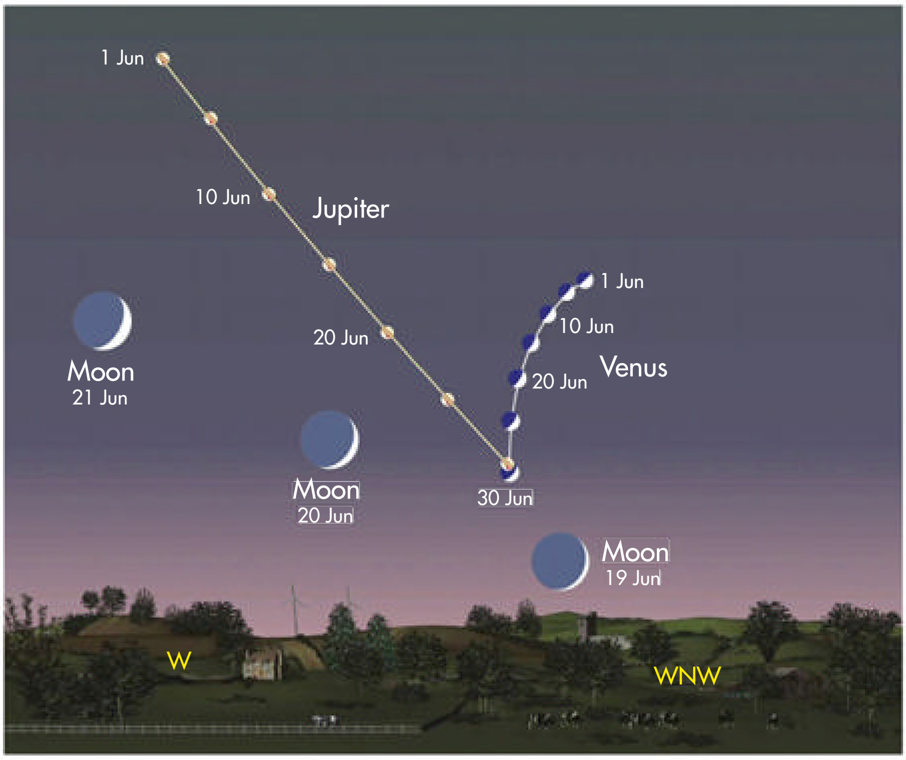
The size of objects in the sky and the distances between them are measured in degrees. The width of your little finger at arm's length spans about 1°.

The planets

PICK OF THE MONTH

VENUS

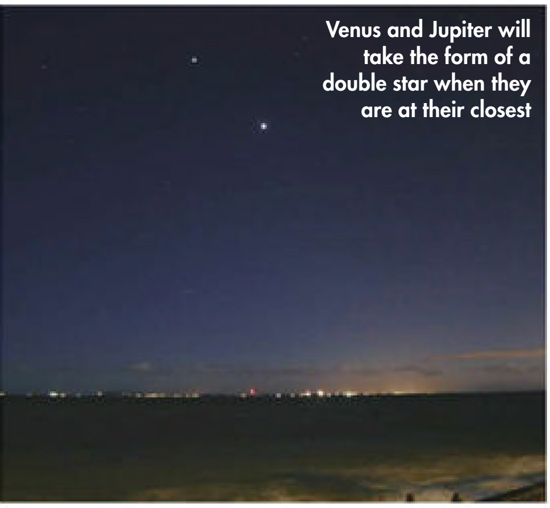
BEST TIME IN JUNE:
1 June 22:00 BST (21:00 UT)
ALTITUDE: 21°
LOCATION: Gemini
DIRECTION: West
RECOMMENDED EQUIPMENT:
6-inch or larger scope at 200-250x magnification
FEATURES OF INTEREST:
Subtle shaded markings, phase



Venus is spectacular in June, though as the month wears on it sets sooner and sooner after the Sun

PETE LAWRENCE X 3

VENUS IS AN evening object, setting some four and a half hours after the Sun at the start of the month. On the 1st, Venus is in line with the stars Castor and Pollux, mag. +1.9 Alpha (α) and mag. +1.2 Beta (β) Geminorum. On this date, the mag. –4.3 planet will be easy to spot low in the western part of the sky. At the end of the month, Venus and Jupiter will be around one-third of a degree apart – see page 50 – and should appear as a double star low in the west-northwest as the sky darkens.



Venus and Jupiter will take the form of a double star when they are at their closest

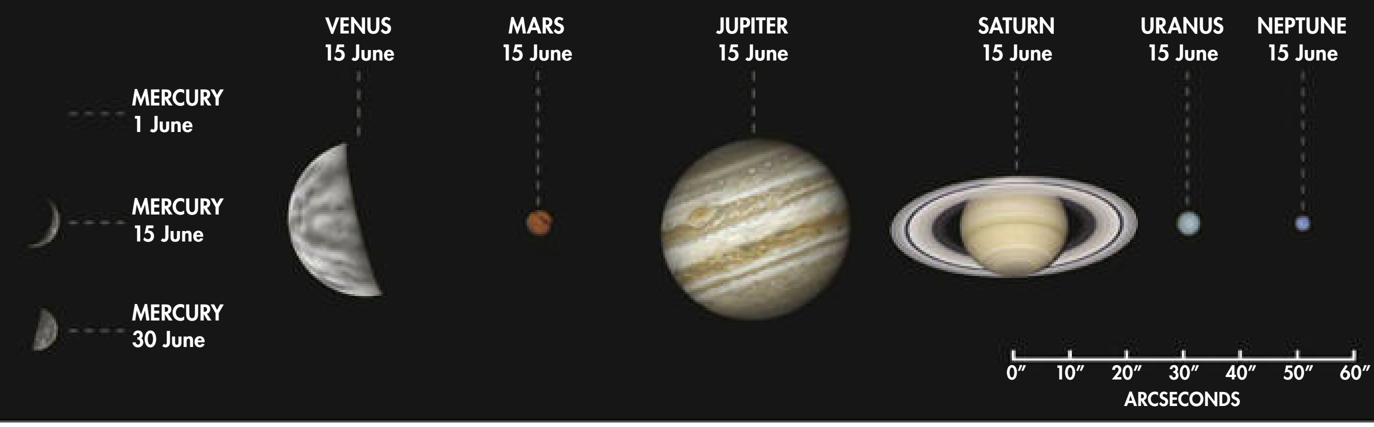
A telescope will show Venus's phase to be just over 50% at the start of the month, declining to 34% by the end. Watch out for the Schröter effect, which describes the fact that the planet's 50% phase doesn't appear when it is predicted to: it's a few days early when the planet is in the evening sky and a few days late when in the morning sky.

Venus reaches greatest eastern elongation on 6 June, when it'll appear separated from the Sun by 45.5°. On 12 and 13 June, Venus will appear to pass across the Beehive Cluster, M44, although the bright twilight sky may prevent the cluster stars from being seen.

By 30 June, Venus sets just two hours after the Sun. This is a prelude to the fact that the planet's position is now rapidly degrading with respect to its altitude above the horizon after sunset. This is something of a shame because as the planet passes around its orbit to the point where it'll be at its closest point to the Earth, it takes the form of a beautiful crescent. At the end of July, Venus's position will mean that the planet will set just after the Sun, so making it difficult to observe in darkening skies.

THE PLANETS IN JUNE

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



SATURN

BEST TIME IN JUNE: 1 June 00:30 BST (23:30 UT on 31 May)
ALTITUDE: 18°
LOCATION: Libra
DIRECTION: South

Saturn is up all night for most of the month, but in a low part of the sky. On 1 June, the full Moon lies 2° to the northeast of Saturn, the pair located to the north of the claws of Scorpius. Saturn culminates – that is, reaches its highest point in the sky, due south – as the sky is starting to get dark from about mid-month onwards. The planet's well presented at this time, with its north pole tilted over by 24° towards Earth. This means that the spectacular ring system is also nicely on view. For this reason, although Saturn only manages to achieve a top altitude of 19° as seen from the centre of the UK, it's still worth trying to get a look at it, if nothing more than to view the rings so well opened up. Saturn will be around mag. +0.5 for most of the month, half a magnitude brighter than the red mag. +1.1 supergiant star Antares (Alpha (α) Scorpii), which lies below and to the left of it. On 29 June, an 89%-lit waxing gibbous Moon lies just over 1° northwest of Saturn as both objects start to set, around 02:30 BST (01:30 UT).

JUPITER

BEST TIME IN JUNE: 1 June 22:00 BST (21:00 UT)
ALTITUDE: 28°
LOCATION: Cancer
DIRECTION: West

Jupiter is past its best for the current period of observation, but detail can still be seen on its 0.5-arcminute disc. For the best telescopic view, try and catch Jupiter at the start of the month as the sky begins to darken. At 22:00 BST (21:00 UT) the planet will have an altitude of around 27°, so the view should remain reasonably steady. Jupiter and Venus are set for a dramatic conjunction at the end of June (see page 50) and this is a good reason to keep tabs on it. On 10 June, mag. –1.7 Jupiter re-enters the constellation of Leo, moving slowly but surely eastward against the background stars. On the 20th, Jupiter marks the right angle in a right-angled triangle formed with Venus and an 18%-lit waxing crescent Moon, low in the west-northwest around 22:30 BST (21:30 UT).

MERCURY

BEST TIME IN JUNE: 30 June 04:00 BST (03:00 UT)
ALTITUDE: 3° (low)
LOCATION: Taurus
DIRECTION: Northeast

Mercury is a morning planet for the whole of June, but not particularly well placed. It reaches greatest eastern elongation on the 24th, when it will appear to be separated from the Sun by 22°. At this time, mag. +0.7 Mercury will be 2° north of mag. +0.8 Aldebaran (Alpha (α) Tauri). You'll need a very flat east-northeast horizon to spot either one of them; look around 04:00 BST (03:00 UT). Mercury's position remains similar for the remainder of the month, but the planet should also appear slightly brighter, reaching mag. 0.0 by the end of June.

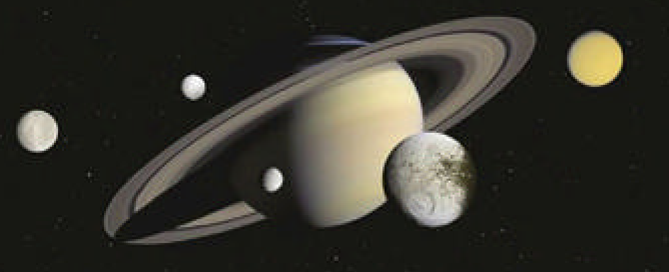
NEPTUNE

BEST TIME IN JUNE: 30 June 02:00 BST (01:00 UT)
ALTITUDE: 14°
LOCATION: Aquarius
DIRECTION: Southeast

Neptune is not well placed but does become visible in 'dark' skies towards the end of the month. The planet is currently mag. +7.9 and around 2° southwest of mag. +3.7 Lambda (λ) Aquarii.

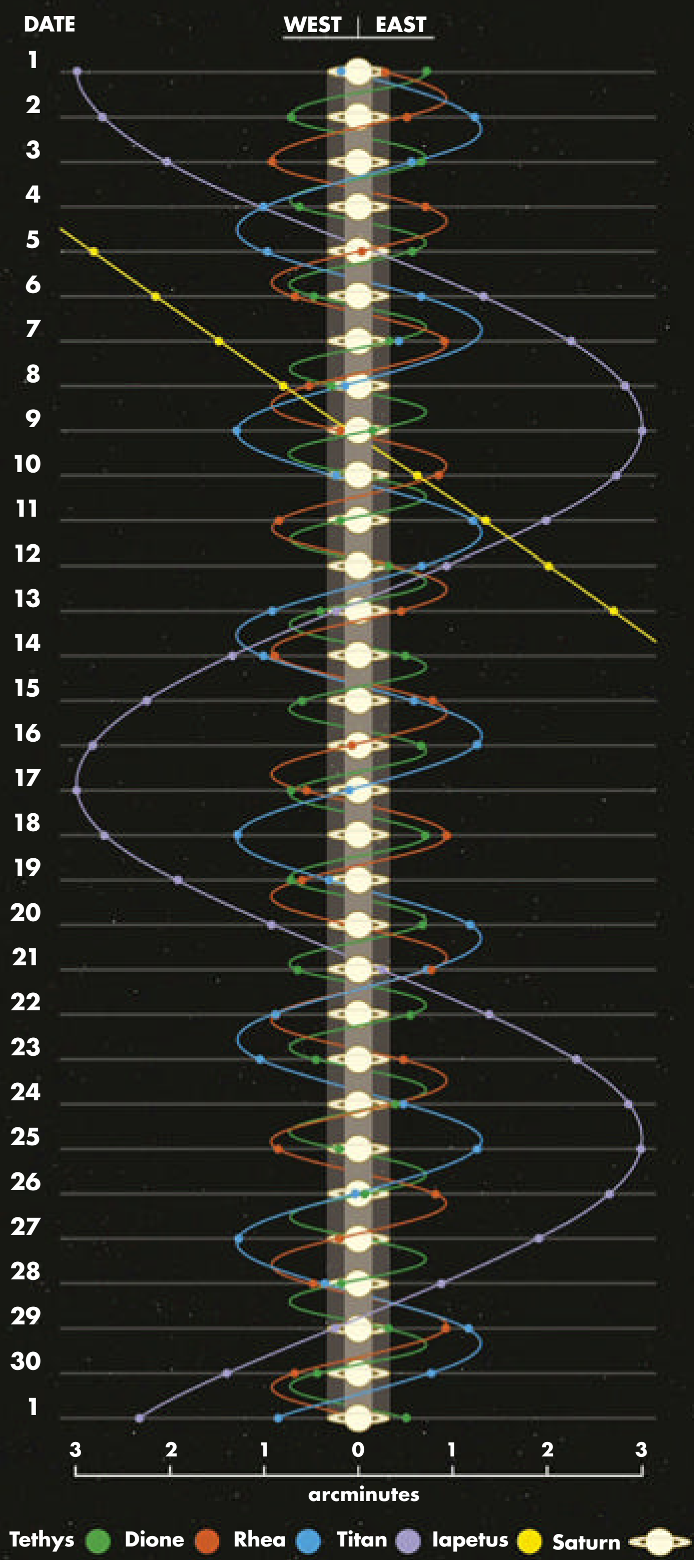
NOT VISIBLE THIS MONTH
MARS AND URANUS

See what the planets look like through your telescope with the **field of view calculator** on our website at:
http://www.skyatnightmagazine.com/astronomy-tools



SATURN'S MOONS June

Using a small scope you'll be able to spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



The Northern Hemisphere

KEY TO STAR CHARTS

- *Arcturus* — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- ASTERISM (Circlet)
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW (N, E, S, W)
- MILKY WAY

WHEN TO USE THIS CHART

1 JUNE AT 01:00 BST
15 JUNE AT 00:00 BST
30 JUNE AT 23:00 BST

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

THE SUN IN JUNE*

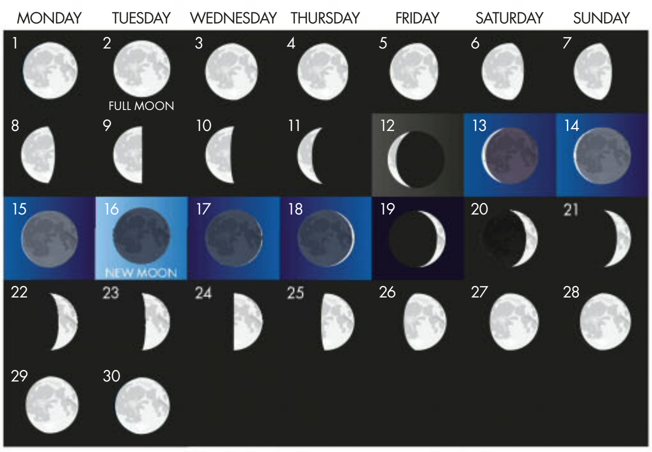
DATE	SUNRISE	SUNSET
1 Jun 2015	04:48 BST	21:28 BST
11 Jun 2015	04:41 BST	21:37 BST
21 Jun 2015	04:40 BST	21:42 BST
1 Jul 2015	04:45 BST	21:41 BST

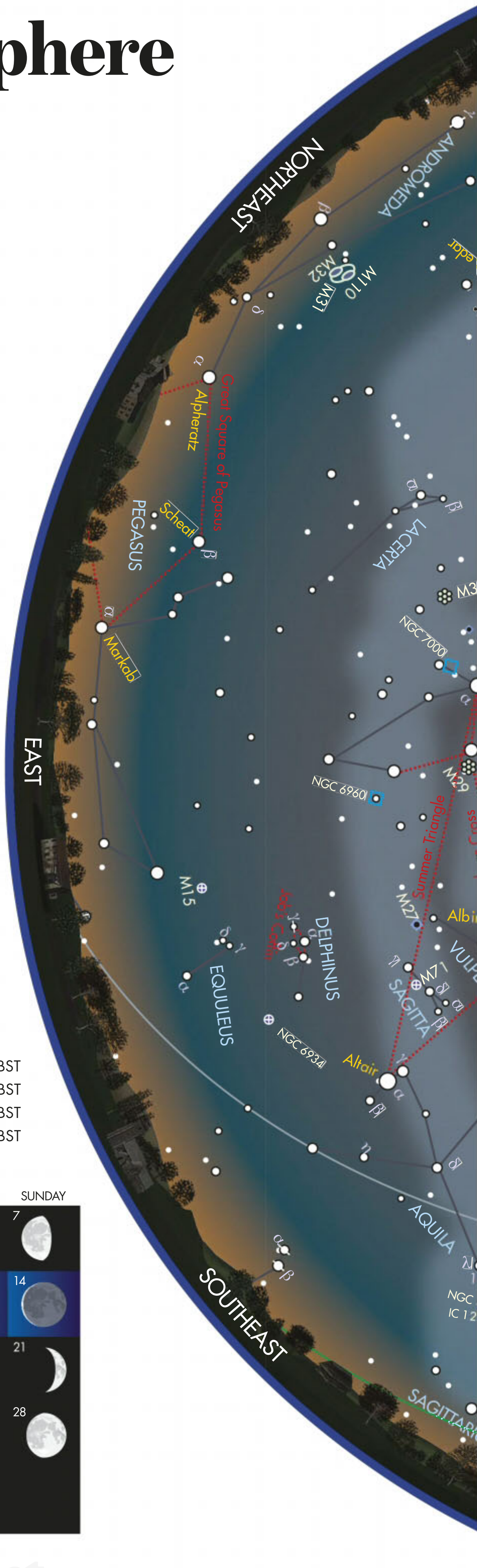
THE MOON IN JUNE*

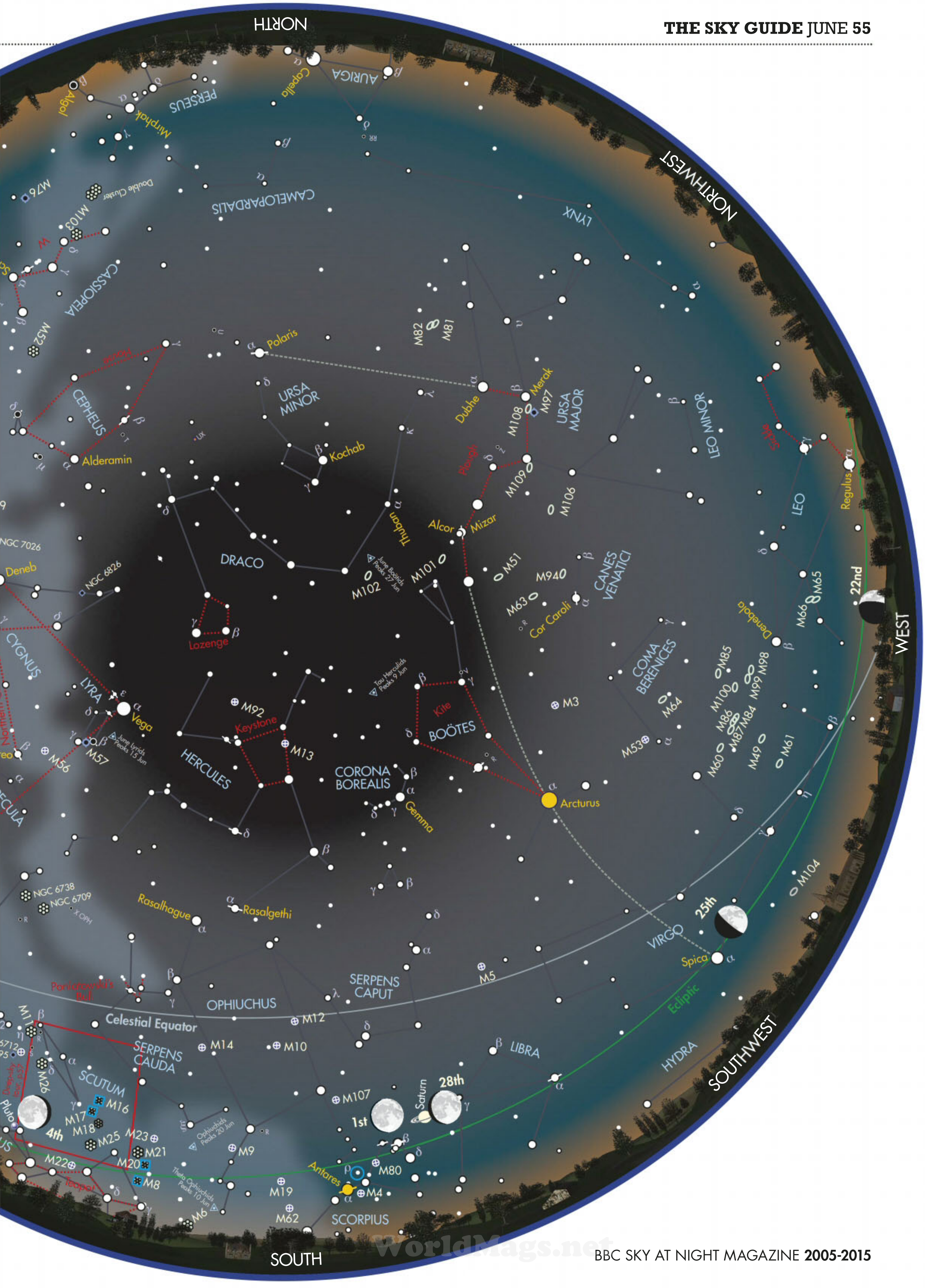
MOONRISE TIMES

1 Jun 2015, 19:59 BST	17 Jun 2015, 05:58 BST
5 Jun 2015, 23:36 BST	21 Jun 2015, 10:08 BST
9 Jun 2015, 01:14 BST	25 Jun 2015, 14:25 BST
13 Jun 2015, 03:05 BST	29 Jun 2015, 18:47 BST

*Times correct for the centre of the UK



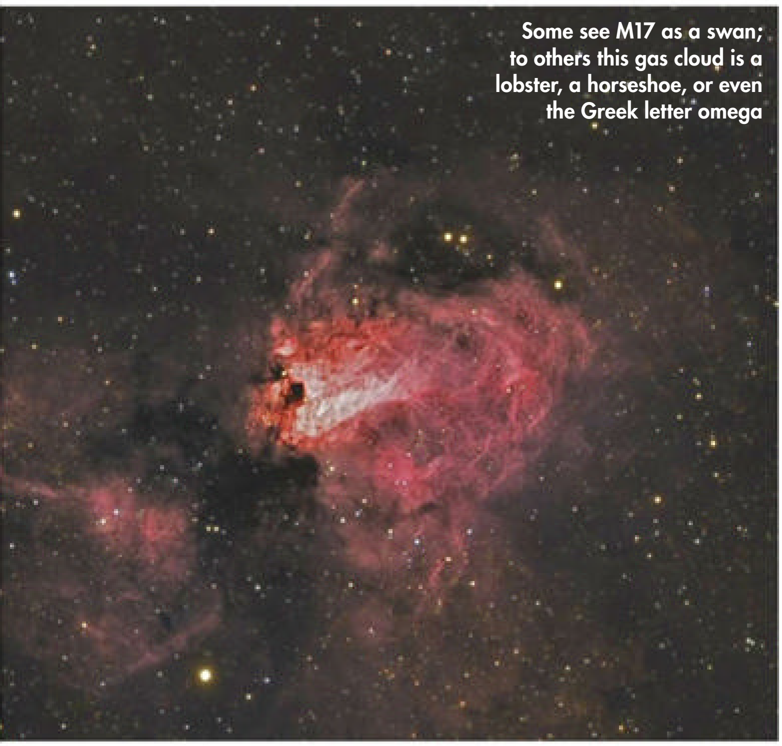



NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
Mirphak
M76
Double Cluster
M103
CAMELOPARDALIS
LYNX
CASSIOPEIA
M52
Polaris
URSA MINOR
Kochab
M82
M81
Dubhe
Merak
M97
M108
URSA MAJOR
LEO MINOR
Sickle
Regulus
LEO
CEPHEUS
Alderamin
Plough
M109
M106
Thuban
Alcor
Mizar
DRACO
NGC 7026
Deneb
NGC 6826
June Boötids Peaks 27 Jun
M102
M101
M51
M94
M63
Cor Caroli
CANES VENATICI
22nd
M66
M65
Denebola
CYGNUS
Lozenge
LYRA
Vega
Tau Herculids Peaks 9 Jun
M92
Keystone
M13
HERCULES
Kite
BOÖTES
M3
COMA BERENICES
M64
M53
M85
M100
M99
M98
M86
M84
M87
M60
M49
M61
M56
M57
June Lyrids Peaks 15 Jun
CORONA BOREALIS
Gemma
Arcturus
M104
NGC 6738
NGC 6709
Rasalhague
Rasalgethi
25th
VIRGO
Spica
Ecliptic
SERPENS CAPUT
M5
Poniatowski's Bull
OPHIUCHUS
Celestial Equator
M12
M14
M10
LIBRA
HYDRA
M11
SERPENS CAUDA
SCUTUM
M26
M16
M17
M18
M25
M23
M21
M20
M22
M8
4th
Pluto
Ophiuchids Peaks 20 Jun
M9
M107
28th
Saturn
1st
Antares
M80
M4
M19
Theta Ophiuchids Peaks 10 Jun
Teapot
M6
M62
SCORPIUS

Deep-sky tour

We journey from a cluster that mimics a constellation to one that is barely a cluster at all

☑ Tick the box when you've seen each one


Some see M17 as a swan; to others this gas cloud is a lobster, a horseshoe, or even the Greek letter omega

1 NGC 6604

Our starting point is the diamond-shaped constellation of Scutum. Imagine a line from mag. +4.2 Beta (β) Scuti to mag. +3.9 Alpha (α) Scuti and carry it on for a little over the same distance again. This will bring you to the area containing our first target, mag. +6.5 open cluster NGC 6604. Despite its proximity to Scutum's shield, NGC 6604 actually lies within the boundaries of Serpens Cauda. The cluster is 5,000 lightyears away and an easy target for small telescopes. Its brighter members form an arc-shaped asterism that bears a passing resemblance to the constellation of Corona Borealis, with one star appearing brighter than the rest. Long exposure images reveal a large expanse of glowing gas catalogued as Sharpless-54. ☐ **SEEN IT**

2 THE EAGLE NEBULA

The cluster in the Eagle Nebula, M16, is 1.6° south of NGC 6604 and faintly visible to the naked eye. A small scope reveals around 15 stars with no nebula, while a 10-inch instrument shows the nebula as a mist surrounding about 30 stars. The nebula fans out east; to the north, it looks as if something's taken a triangular bite out of it. Southeast of the cluster are the darker features that form the shape of an eagle carrying a fish. These are the dark star-forming regions that have been known as the Pillars of Creation ever since the iconic Hubble Space Telescope image brought their stunning beauty to the fore. ☐ **SEEN IT**

3 THE SWAN NEBULA

The Swan Nebula, M17, is 2.3° south (and slightly east) of M16. This large patch of relatively bright nebula has an apparent size of around 40x30 arcminutes and is an easy find even in binoculars. Telescopically, its most obvious feature is a bright bar, which looks mottled in a 10-inch instrument. A 'hook' extends from a brighter region along the bar, forming the swan's neck. Larger apertures show lots of wispy nebulosity, particularly behind the bird's head. The associated cluster lies north of the main nebula and contains around 50 stars. Depending on how vivid your imagination is, M17 is also known as the Omega, Lobster and Horseshoe Nebula! ☐ **SEEN IT**

4 M18

Head south from M17 for just over 1° and you'll arrive at mag. +6.9 open cluster, M18. In a small scope the cluster is fairly unremarkable, with around a dozen stars on view. Larger apertures reveal more members, perhaps doubling the count. The cluster then appears to run out of steam. The brighter members form a triangular pattern and with a bit of imagination, it's also possible to see a curved line of stars off to the southwest. Together they give M18 the appearance of a celestial arrow, although it's not immediately obvious what it's pointing at. M18 is estimated to be 32 million years old and lies 4,900 lightyears from Earth. ☐ **SEEN IT**

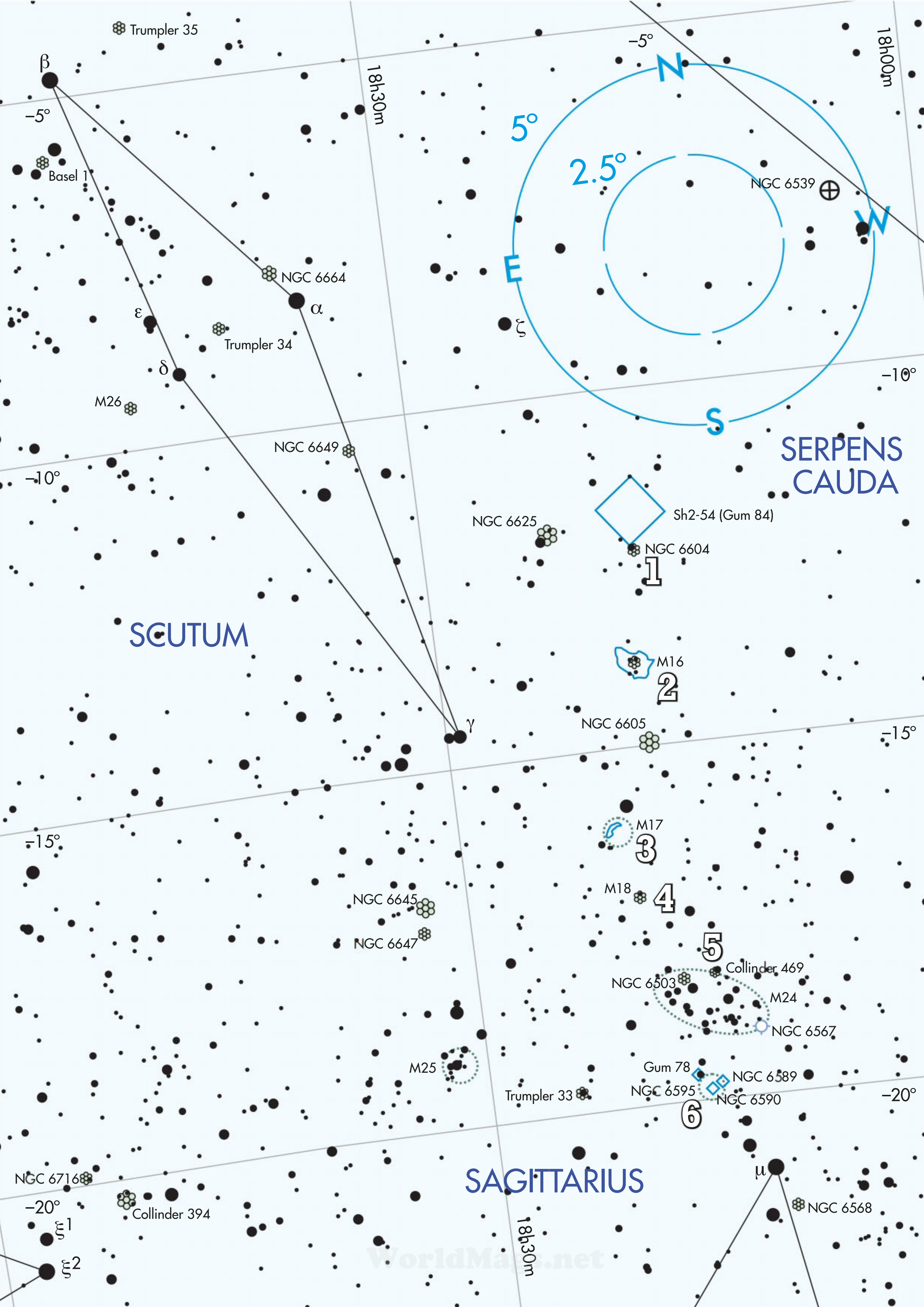
5 M24

M24 is also known as the Small Sagittarius Star Cloud and Delle Caustiche. It's an incredibly star rich region visible to the naked eye 1° south of M18. The star cloud itself appears a little over 1.6° by 1.2° and so best suits a wide-field scope with a low-power eyepiece. There are thousands of stars on view here as well as several embedded open clusters such as 11th-magnitude NGC 6603. A thinning of the dark dust that blocks the light from the core of the Milky Way creates a window through which we can see the stars that make up M24. ☐ **SEEN IT**

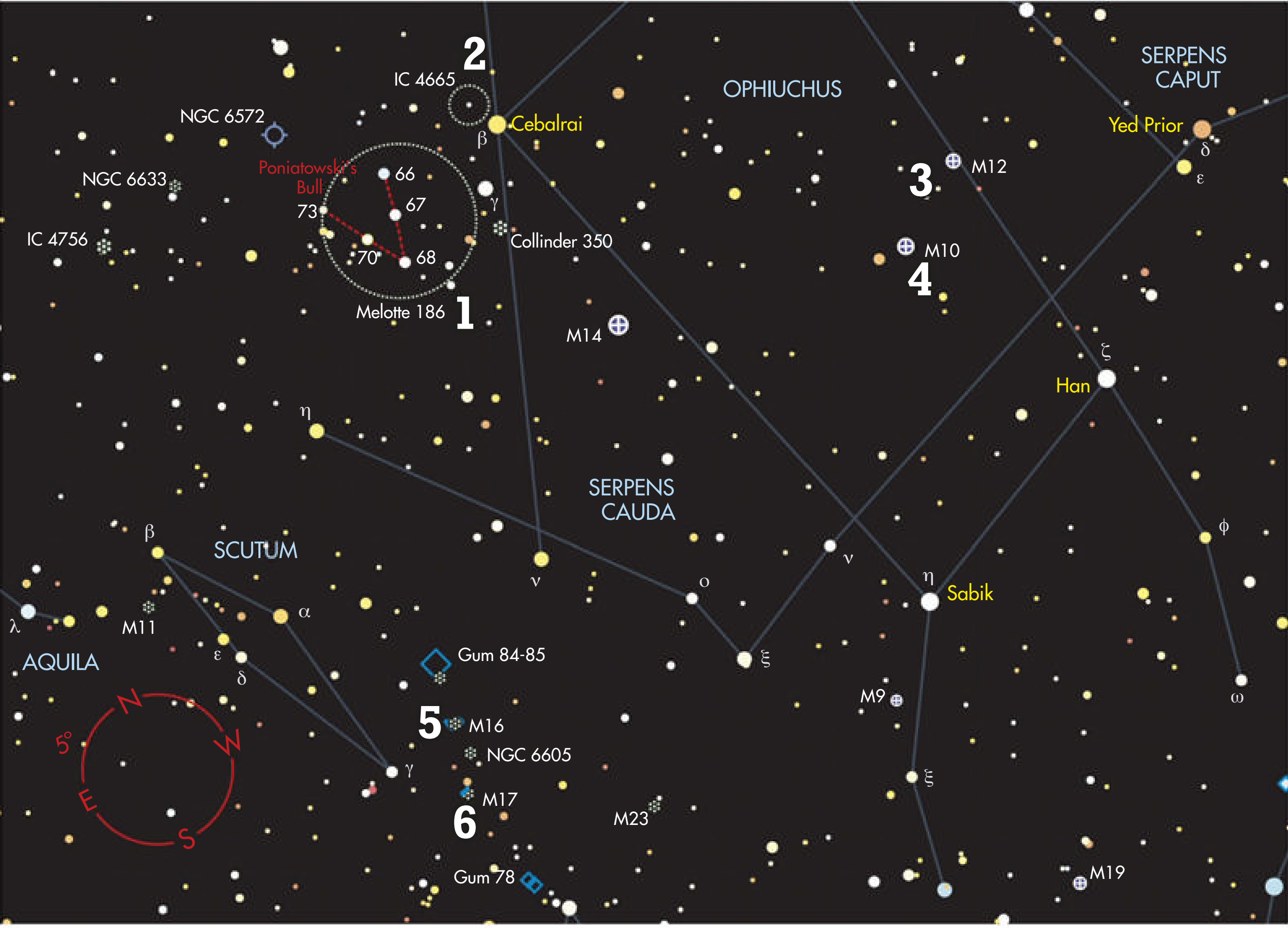
6 NGC 6595

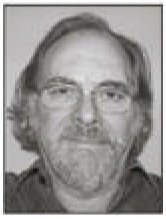
Our final target is 'open cluster' NGC 6595, lying 1° south of M24. Actually, when looking for a cluster, you might struggle as the coordinates point to a pair of stars. There appears to be some controversy over NGC 6595, which may have resulted from a misclassification. Whatever the reason, there's still something of interest here as the pair of stars are enshrouded by nebulosity, which should be fairly easy to detect even with a small telescope. If you have a 18-inch or larger scope, see if you can detect a dark patch lying just southwest of the main stars. This appears to be a dark nebula or possibly a star-forming globule. ☐ **SEEN IT**

CHART: PETE LAWRENCE, PHOTO: ISTOCK



Trumpler 35
β
−5°
Basel 1
18h30m
18h00m
−5°
N
5°
2.5°
NGC 6539
W
E
NGC 6664
α
ε
ζ
Trumpler 34
δ
−10°
S
M26
SERPENS
CAUDA
NGC 6649
−10°
NGC 6625
Sh2-54 (Gum 84)
NGC 6604
1
SCUTUM
M16
2
γ
NGC 6605
−15°
M17
3
−15°
M18
4
NGC 6645
NGC 6647
5
Collinder 469
NGC 6503
M24
NGC 6567
M25
Gum 78
NGC 6589
Trumpler 33
NGC 6595
NGC 6590
−20°
6
NGC 6716
SAGITTARIUS
μ
−20°
Collinder 394
NGC 6568
ξ1
18h30m
ξ2





Binocular tour

A second Bull, an eagle and a swan fill the celestial menagerie of this month's tour

With
Stephen Tonkin

☑ Tick the box when you've seen each one

1 MELOTTE 186

10x50 Our tour begins with an easy object that seems to be made for binoculars: open cluster Melotte 186, which is also known as Collinder 359. It spans 4° and so is comfortably contained in the central sweet spot of 10×50 binoculars. The cluster includes a prominent V of five stars: 66, 67, 68, 70 and 73 Ophiuchi. This shape is reminiscent of the Hyades in Taurus, a similarity that led to this region gaining the name Taurus Poniatovii (Poniatowski's Bull) in the 18th Century. One particularly striking thing about Melotte 186 is the variety of colours of its brighter stars. ☐ **SEEN IT**

2 THE SUMMER BEEHIVE

10x50 The Summer Beehive, officially IC 4665, is the cluster that greets you to the summer skies: look for a particularly attractive curved chain of bright white stars, which forms part of the letter 'H' in the inverted word 'HI'. This large cluster, which is in the same field of view as mag. +2.8 Cebalrai (Beta (β) Ophiuchi), is delightful in binoculars of any size. You should easily be able to resolve about a dozen stars with a pair of 10×50s. ☐ **SEEN IT**

3 M12

10x50 Globular cluster M12 lies very close to the northeast point of an equilateral triangle that has mag. +2.7 Yed Prior (Delta (δ) Ophiuchi) and mag. +2.5 Zeta (ζ) Ophiuchi as the other points. Shining at mag. +6.7, it is one of the larger and brighter southern globular clusters visible from Britain. It is an easy object in 10×50 binoculars in moderately good skies, though its core is very indistinct for a globular and it was once suspected to be a compact open cluster. It is now believed that many of its low mass stars have been stripped away by the Milky Way's gravity. ☐ **SEEN IT**

4 M10

10x50 If you place M12 at the northwest of the field of view our next target, the globular M10, should be near the opposite side of the field. It is approximately the same size as M12 but slightly brighter. If you mount the binoculars, you should find that averted vision shows a much more distinct brightening of the core compared to M12. If you haven't tried averted vision, M10 and M12 provide a good opportunity: put both in the field of view and, when you direct your gaze to one of them, you should notice the other grow and brighten. ☐ **SEEN IT**

5 THE EAGLE NEBULA

15x70 To find the Eagle Nebula, M16, put mag. +4.7 Gamma (γ) Scuti at the southeast of the field of view and the cluster will be just west of centre. This is the object that became famous through Hubble's Pillars of Creation image, but unless your skies are very good you will probably will not be able to see any of the nebulosity – only the cluster. If you have an ultra high contrast filter, try holding it over one of the eyepieces to make the nebulosity visible: you may be able to identify the shape of the wings and tail from which this object gets its popular name. ☐ **SEEN IT**

6 THE SWAN NEBULA

15x70 Navigate 2.5° south of M16 to find the Swan Nebula, also known as the Omega Nebula and designated M17. You should initially see an elongated oval patch of greyish light about 10 arcminutes long. Keep it centred while you look at the mag. +5.3 star about 0.5° north of it, and averted vision should reveal a small hook-like extension stretching south from the top of the patch. This gives the nebulosity the guise of an inverted tick-mark. ☐ **SEEN IT**

CHARTS AND PICTURES: PETE LAWRENCE

Moonwatch

Crater Orontius

AS CRATERS GO, battered Orontius is among the oldest on the Moon. Its definition has suffered because of this and its walls are overlaid by numerous younger impacts. Centre-to-centre it lies about 190km northeast of 86km-wide crater Tycho, and is the third and most northern of a south-north run of walled plains that starts in the south with Clavius (225km wide) and has Magnius (164km) in the middle.

Only small sections the original wall of Orontius remain: one in the southwest and another to the north. Even these regions appear peppered with tiny craterlets. One impressive intrusion is the way the crater wall of Sasserides A (48km) bulges impertinently into Orontius. It almost looks as if the younger Sasserides A has jostled against Orontius, forcing the larger crater's western wall to curve the wrong way.

Bowl-shaped Orontius D (15km) sits at the northern intersection of Orontius's rim with that of Sasserides A. Follow the rim of Orontius to the east from D to arrive at the similar looking Orontius C (also 15km). Both craters show light rims in the phases around full Moon and can be used to find Orontius at such times.

South of C, and occupying the upper quarter of Orontius's floor is Orontius F (45km). It is heavily eroded and barely visible under direct lighting, and so best seen when the terminator is near. Large scopes may reveal that F's floor appears smoother than that of Orontius.

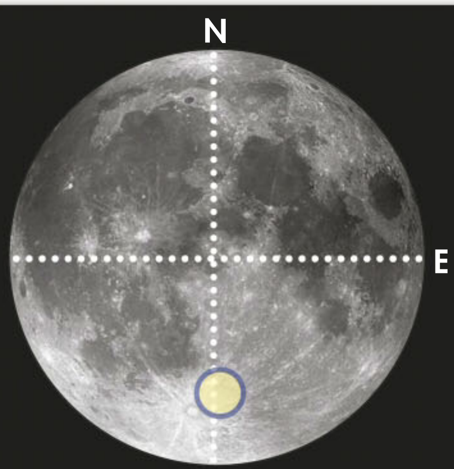
The eastern rim of Orontius is scarred beyond sensible recognition. The southeast part is overlaid by Huggins (65km), the eastern wall of which has been replaced by Nasireddin (53km). Immediately north of Nasireddin is Miller (75km), providing the appearance of a more conventional lunar crater with terraced walls, a flat floor and a central mountain peak.

To the south of Orontius is Sassure (55km), worn but well defined. It has a constant sloping rim leading down to a flat floor. However, there appears to be an 80km outer ring of another, more ancient crater that has been more or less obliterated by Sassure. This is easier to see under oblique illumination. Sassure is virtually concentric within the larger crater.

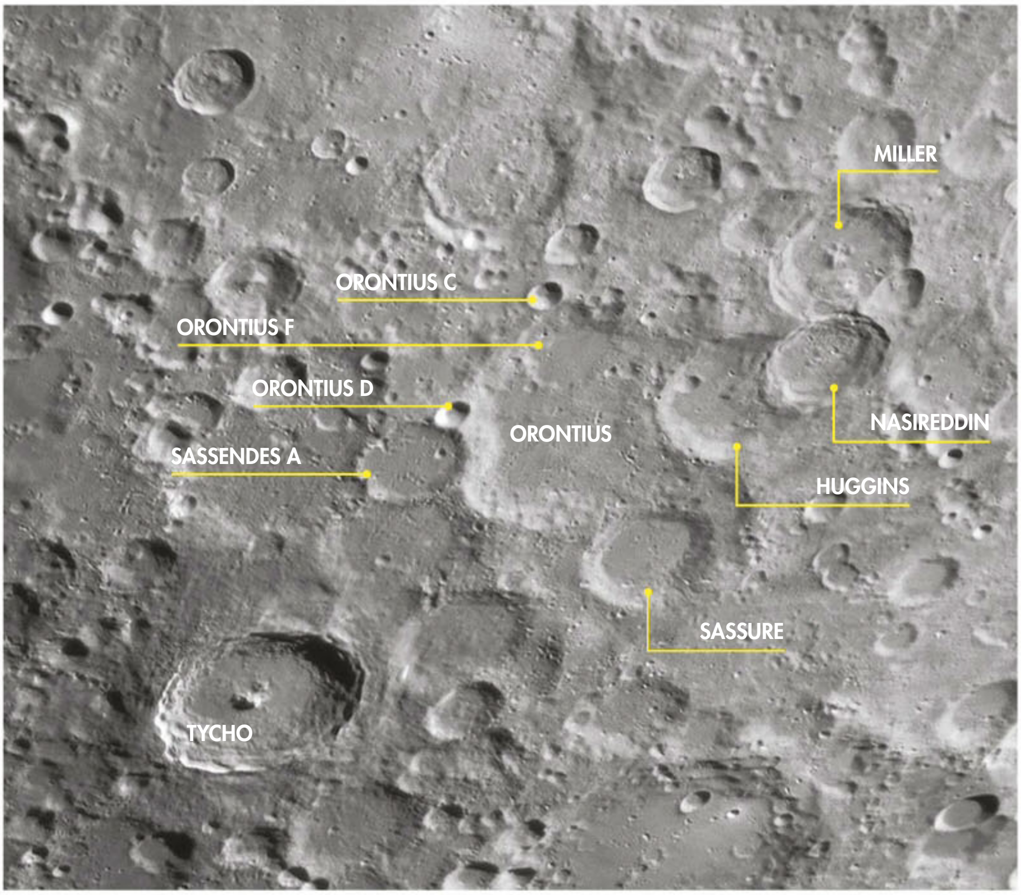
As the Sun rises high in the lunar sky, relief shadows disappear and you're left with a view of Moon that relies on the reflectivity of the surface. The southern highlands become difficult to navigate at such times, but help is at hand from Tycho, which sits at the centre of an impressive system of bright rays. A particularly prominent ray heads east from Tycho, eventually crossing Mare Nectaris some 1,400km away. This ray crosses Orontius completely, its southern edge coinciding with what's left of the crater's southern rim.

STATISTICS

TYPE: Crater
SIZE: 125km
AGE: 3.9-4.6 billion years old
LOCATION: Latitude 40.4°S, longitude 4.0°W
BEST TIME TO OBSERVE: First quarter or six days after full Moon (7-9 June or 24-28 June)
MINIMUM EQUIPMENT: 10x binoculars



"Only small sections of the original wall remain; even these are peppered"



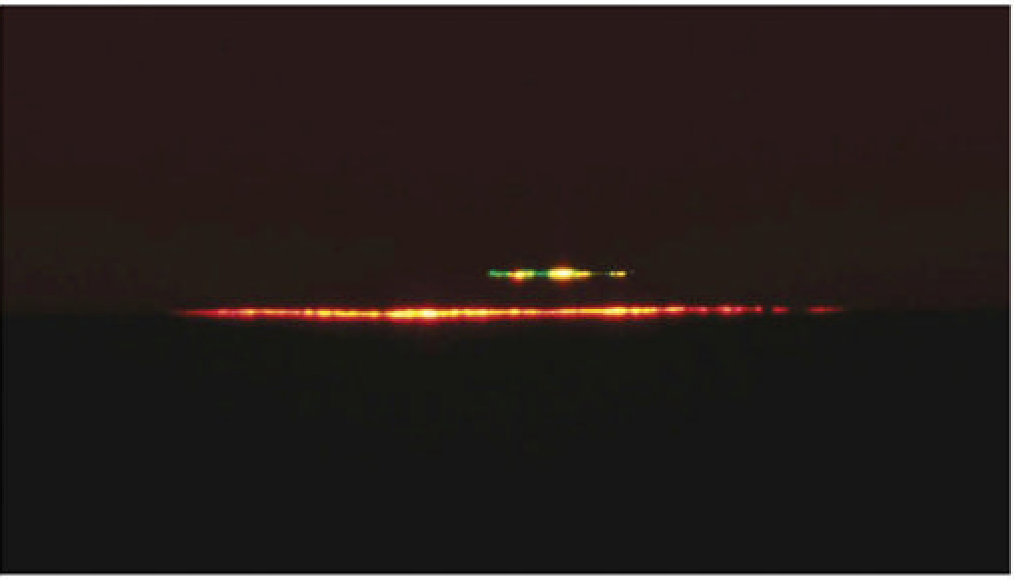
Not only is Orontius not far from Tycho, one of the famous crater's rays strikes straight through its middle

Astrophotography

Photographing the Green Flash

RECOMMENDED EQUIPMENT

A digital colour camera with a 200mm or longer focal length lens and live preview, neutral density solar filter, tripod, shutter release cable



With luck, you'll catch a true Green Flash – a vivid line of emerald light hanging above the horizon

THE SUMMER SOLSTICE occurs on 21 June. At this time the Sun's declination reaches its maximum value for the year – good circumstances, in other words, to try and capture what was once considered a rare and location-dependant phenomenon known as the Green Flash. Though it is often associated with the tropics, the Green Flash can be successfully recorded from the UK. Its appearance may not be as dramatic as from those latitudes, but it is still essentially the same thing.

The atmosphere acts like a giant prism, with light passing through being refracted, or bent. The amount of refraction depends on how thick the layer of atmosphere is that the light has to travel through, and also varies by wavelength; shorter wavelengths appear more refracted than longer ones. This effect is called dispersion and results in an object's light being spread into a spectrum of colour. Dispersion gets more noticeable at lower altitudes. High up you'll hardly notice its effect, but low down a single star may, at high magnification, spread into a complete spectrum.

The effect is a nuisance on low-altitude planets imaged with colour cameras because it colour-blurs fine detail. Objects with a large apparent diameters such as the Sun and Moon also exhibit dispersion, but their size dwarfs the effect. You can see the effect when they are rising and setting – the usual safety precautions must be observed in the case of the Sun of course! The object is spread into many different coloured images. Most overlap, causing a slight blur in detail, but at the extreme upper and lower edges, blue and red colour fringes should be seen.

The effect is quite small and easily mistaken for lens colour fringing. The blue fringe typically doesn't survive because the atmosphere scatters it away. What remains is a green fringe around the upper edge of the Sun or Moon to complement a red one around the lower edge. Together these fringes are known as the Red Rim and the Green Rim. Both can be seen when either the Sun or Moon are very near the horizon.

The Green Rim is one component of the Green Flash, but to make the flash work, the green edge must be somehow separated from the Sun's disc. This occurs when a temperature inversion layer is present. Under normal conditions, atmospheric temperature decreases with height. An inversion layer occurs when a layer of warmer air interrupts this decrease.

When the inversion layer is below you, it can cause a mirage, which effectively picks off and magnifies a thin slither of whatever happens to be behind it, like a cylindrical lens. If this happens in front of a Green Rim, the result may appear to detach from the Sun's disc and appear vividly green. This is the Green Flash.

A proper Green Flash occurs when the Sun has just slipped below the horizon, leaving just a vivid emerald green line of bright light hovering over the horizon. However, the effect can sometimes be seen when the entire disc is above the horizon. A seaward horizon is best, but the Green Flash can sometimes even be seen when the Sun is slipping down behind clouds which appear close to the horizon.

If you're observing from a location with particularly clean and thin air, such as you'd get at high altitude, blue light scattering is reduced and this can result in a very rare Blue Flash.

KEY TECHNIQUE

SCALING THE SUN

The brightness and large apparent size of the Sun can make it hard to identify the effects that dispersion creates. A decent image scale and accurate focus are essential to reveal them because blurring effects can easily hide what you're trying to record. Once this has been mastered, capturing the Green Flash is down to luck and timing. Watching the Sun via your camera's rear viewscreen allows you to predict how atmospheric ripples roll up the Sun's disc and catch that brief instant when the flash may occur.

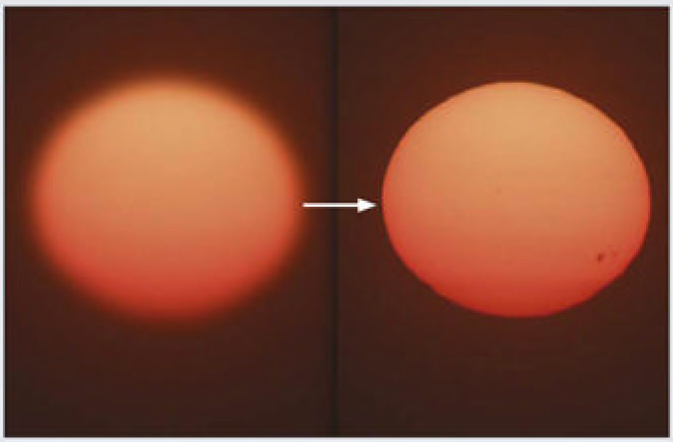
Send your image to: hotshots@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

STEP-BY-STEP GUIDE

WARNING: Only attempt this if the Sun is setting over a true horizon like you'd have over the sea. A false horizon such as hills or buildings will mean the Sun may be still high enough in the sky to damage your camera.

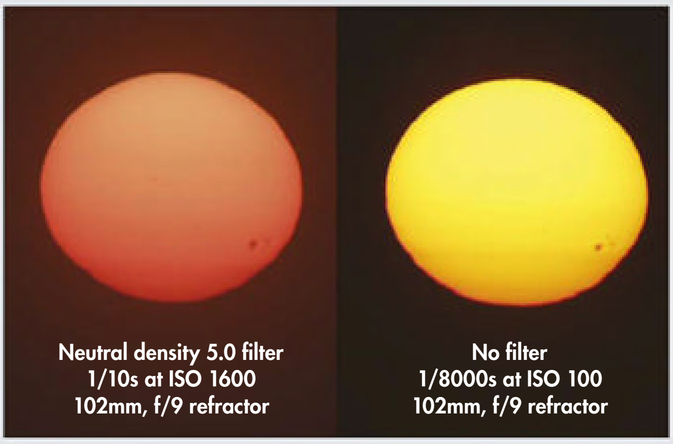
STEP 1 Safety is paramount. Never look directly at the Sun or view it through your camera's viewfinder; only look at it through the review screen. A camera may typically be pointed at the setting Sun as the solar disc is about to touch the true horizon. Note that you risk damaging your camera if you get the timing wrong – do so at your own risk.



STEP 2 A 200mm lens will produce a decent solar disc but a 1,000mm refractor creates a really dramatic view. Fit the refractor or lens with a neutral density solar filter such as the popular Baader Astrosolar Film; also make sure any finders are covered. Focus using your camera's live view function using the edge of the Sun or any large sunspots.

STEP 3 The filter can remain in place until the Sun starts to set. Set the ISO relatively high, to say 400 to 800, then adjust the exposure so that the Sun's disc is not overexposed. Check the image histogram (you can normally do this by pressing an 'Info' button when an image is displayed) and ensure that the image data is contained between the left and right extremities of the graph.

STEP 4 You will need to vary your exposure length as the Sun sinks and the sky dims. Keep watching the image on the camera's rear screen, looking for ripples that travel up the Sun's disc. When one gets close to the top take a burst of images. Continuous shooting mode (circled) and a shutter release cable will stop you from wobbling the camera.



STEP 5 As the last bit of Sun slips below the horizon, it should be possible to remove the front safety filter from your telescope or lens. Again, don't look directly at the Sun through the camera's viewfinder – use the review screen. You will still need to reduce the exposure. Keep taking continuous shots until the Sun has well and truly set.

STEP 6 Examine your shots on a computer screen, paying particular attention to the upper edge of the Sun. It's not uncommon to see the Green Rim extending off the edge of the Sun's disc but not fully detached. Obtaining a true Green Flash may take many attempts but is great fun to chase. Once you've got one, why not try for the lunar equivalent?

AVOIDING ARMAGEDDON

There's a very real risk that one day an asteroid could wipe out all life on Earth. **Elizabeth Pearson** finds out what's being done to avert a calamity

ASTEROID DAY
30 June 2015
www.asteroidday.org

Are we doing enough to avoid our own extinction? It's a question that has been put forward by a group of over 100 influential people – from scientists and astronauts to artists – who have all signed the Asteroid Day Declaration. A meteor strike could easily send us the way of the dinosaurs, they say, and we must do more to ensure the survival of our species.

On 30 June 1908 an asteroid exploded high in the atmosphere above Siberia, its shockwave flattening 2,000 square km of woodland near the Tunguska River. It was the most destructive asteroid to have struck Earth in living memory, and it is on the anniversary of this event that Asteroid Day itself will take place.

Asteroid strikes such as that at Tunguska happen once a century on average. Fortunately most of Earth's surface is unpopulated, but it could have been a very different story. Two years ago a meteor exploded over the Russian town of Chelyabinsk. Though smaller than the 1908 asteroid, the blast was large enough to blow out windows, and caused millions of pounds worth of damage. Around 1,500 people were hospitalised with cuts from glass and burns from the bright glare of the meteor. But even this could be considered lucky. The Chelyabinsk meteor was comparatively small and the area was remote.

The worst case scenario

If the larger Tunguska event had happened over London, then an area the size of the M25 would have been obliterated, and the effects would have reached further still. People across central England would have been knocked off their feet and even been burned by the blast. Those as far away as Glasgow and Edinburgh would have felt the shockwave. And this asteroid was still only a few dozen metres long. There are much larger asteroids that could wipe out countries, continents or even cause mass extinction.

> "If the Tunguska event had happened over London, an area the size of the M25 would have been obliterated"

The threat of these potential killers is far from unknown. There are dozens of fictional films and books about how we would save the world from an imminent impact. Most often the planet's salvation involves a daring last-minute space mission and large quantities of explosives.

▲ The 1908 Tunguska event was the most devastating asteroid impact in recent history; we were lucky that it happened away from urban areas

▲ One of the most recent and famous events was that in Chelyabinsk in February 2013; the space rock shone brighter than the Sun as it fell

But in reality blowing up an asteroid a few days before impact would be disastrous, turning a single bullet into a shotgun blast.

"If we broke up a 100m-diameter asteroid, it could create as many as 100 objects as large as the one that hit in Chelyabinsk in 2013," says Harold Reitsema, mission director of the Sentinel infrared survey mission. "Even if most of these were to miss the Earth, there could be substantial damage from the remaining pieces."

If, on the other hand, an Earth-bound asteroid were found a few decades in advance, then only a small change in its orbit would be needed to make it miss the planet. "The preferred approach would be to use the 'kinetic impactor' deflection technique, which involves hitting the asteroid with a spacecraft moving at high velocity," says Reitsema. "The impact would change the speed of the asteroid and cause it to miss Earth. For this to work, we need a lot of time – preferably at least a decade."

The problem is we are not detecting nearly enough of them. Currently only one per cent of 'city-killer' asteroids are known about.

"The challenge with asteroid detection is that they are small, dark and far away," says Reitsema. "The fix for this is to observe with more telescopes, and to do it for many years. The intent of Asteroid Day is to bring the potential for understanding the asteroid threat to the public's attention."

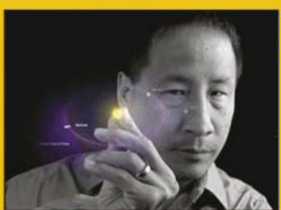
The event aims to raise awareness of the problem, asking governments and nations to fund research and detection networks with the aim of increasing the detection of asteroids to ensure we don't all go the way of the dinosaurs. "We have the potential to find an object that would hit the Earth well before it does, and could prevent the impact from occurring," says Reitsema. "Now we need to focus on achieving that capability." Ⓢ

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University.

THE **EXPERT**

Ed Lu is a former astronaut and head of the B612 Foundation, dedicated to defence against asteroids



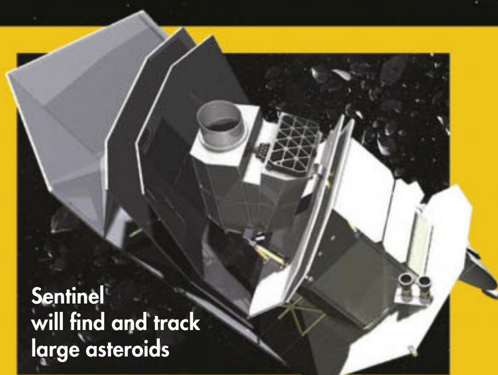
"Say an asteroid such as the Chelyabinsk meteor hit directly over London. It would have killed millions of people. London is also a centre of banking and commerce, so what would happen to the world economy? It could collapse. It could take centuries to recover. It would take three generations for society to return to how it was before, and for your grandchildren to live in a normal world. All because of a rock 20m across.

The purpose of Asteroid Day is for people to understand two things. One, that asteroids are a serious long-term issue and two, that we can do something about them.

As things stand today we just do not know when the next asteroid is going to hit. We need to find 100 times more asteroids than we're finding today, at a rate 100 times greater than we are achieving today. That's why we are building Sentinel.

Sentinel is an infrared telescope that will launch in 2019. It will do the hard part of protecting the world from asteroids by detecting and following 90 per cent of asteroids greater than 140m across.

What most people don't realise is that deflecting asteroids is relatively easy. The part that's stopping us now is finding them. The idea is to find these asteroids not just when they're days or weeks away like they do in

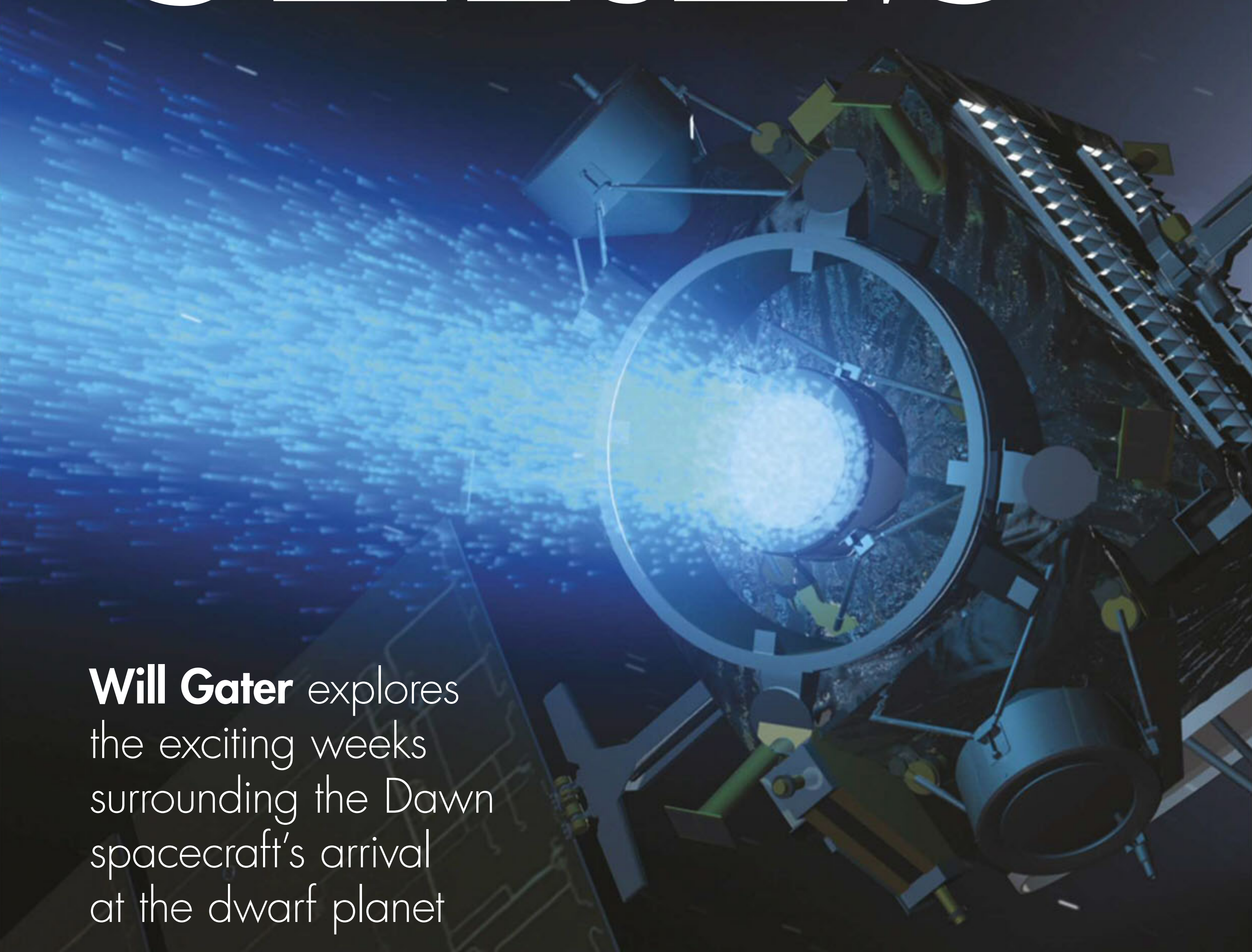


Sentinel will find and track large asteroids

movies. We want to catch them decades before they reach Earth.

If an asteroid is going to hit the Earth in 50 years, how far away from us is it? It's got many billions of kilometres to travel before it hits. That makes the job of deflecting it much easier; you just need to change its speed by a small amount. All you need to do then is run a spacecraft into it. We did that with a comet during the Deep Impact mission in 2005, and you can do the same thing with an asteroid. It is quite simple and it has been done."

SUPRISES AT CERES



Will Gater explores the exciting weeks surrounding the Dawn spacecraft's arrival at the dwarf planet

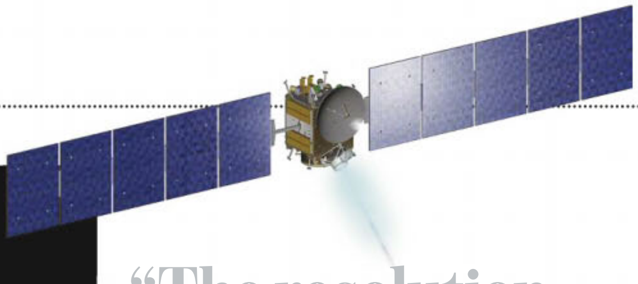
NASA/JPL-CALTECH, WALTER MYERS/SCIENCE PHOTO LIBRARY

If your long car journeys to the beach this summer elicit the plaintive cry of 'Are we nearly there yet?' from a back seat, spare a thought for the scientists working on NASA's Dawn mission. It set off in September 2007 and has spent seven and a half years sailing toward the asteroid belt on a trip that's clocked up a staggering 4.9 billion km. Much of that has involved the spacecraft quietly slipping through space, but along the way Dawn stopped off at one of the largest asteroids in the Solar System, the 569km-wide Vesta.

Dawn entered into orbit around gnarled Vesta in July 2011 and spent almost 60 weeks mapping and studying the asteroid with its quartet of instruments. Results from the spacecraft's camera, as well as its visible and infrared spectrometer – which analyses the composition of the surface – showed that curious patches of dark material seen in some areas were likely the remains of an asteroid that had crashed into Vesta's southern hemisphere billions of years ago. Pictures from the onboard camera also revealed spectacular landslides beneath vast scarps on the craggy and cratered space rock.

Dawn's final destination though was the dwarf planet Ceres – 950km across and by far the most enigmatic body orbiting between Mars and Jupiter. The probe arrived there in March this year, ▸

Dawn entered the orbit of Ceres in March, becoming the first probe to circle two Solar System bodies as it did so



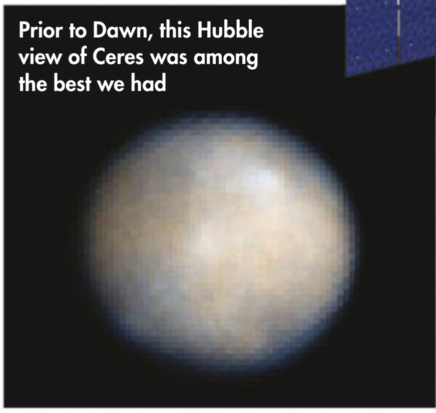
▸ yet even before it had settled into orbit its camera spotted something that had scientists around the world talking.

Up until Dawn approached Ceres, our best view of the dwarf planet had been from images taken with the Hubble Space Telescope in December 2003 and January 2004. As Dawn crept closer, the little disc with subtle shadings that Hubble had seen years before slowly morphed into a world looming large in the camera's field of view. "The results were more real than the Hubble images because of the higher resolution," says Lucy McFadden, who was part of the team that used Hubble to observe Ceres and is now a co-investigator on the Dawn mission.

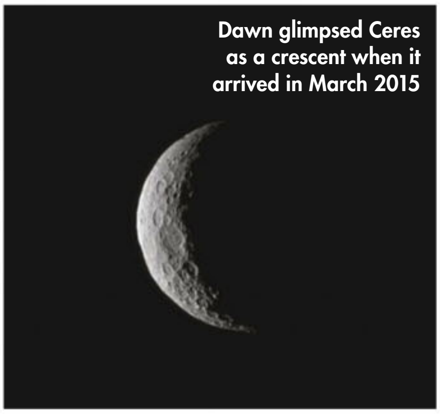
By late January 2015 the resolution of Dawn's images had gone far beyond what Hubble could achieve and subtle textures began to show on Ceres's surface. From a distance of some 237,000km, the probe's camera showed the dwarf planet spinning slowly against the deep black of space.

The pictures had a practical use too. "Our approach observations were designed to get to know Ceres," says Carol Polanskey, Dawn's science operations manager. "The spacecraft navigators need to improve their knowledge of Ceres's spin axis, shape, and rotation period. Of course, the side benefit is that we begin to see the first clues of what Ceres will soon reveal." Those 'first clues' included one of the biggest surprises of Dawn's mission so far.

"It is always exciting when a space mission reaches an object that has never before been visited," says Ulrich

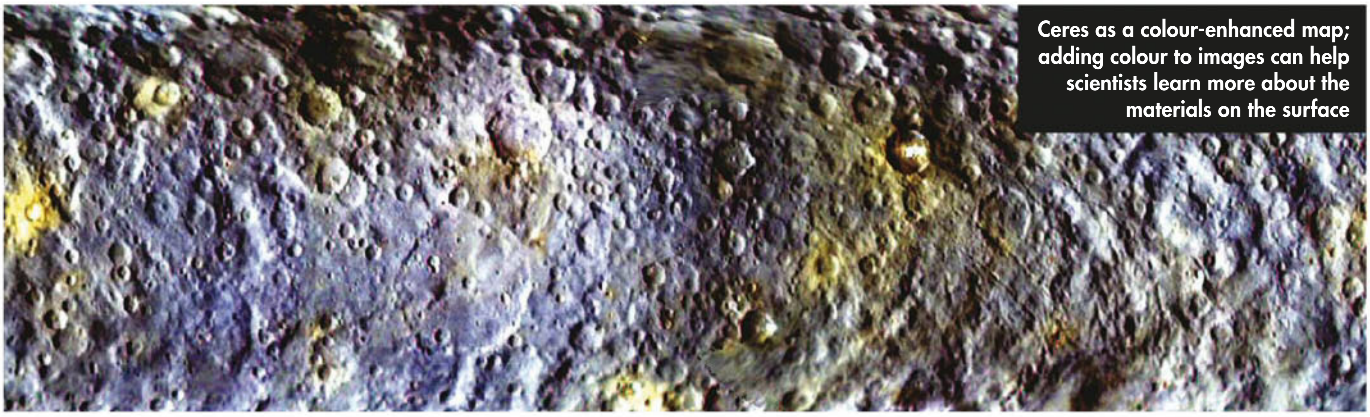


Prior to Dawn, this Hubble view of Ceres was among the best we had



Dawn glimpsed Ceres as a crescent when it arrived in March 2015

"The resolution of Dawn's images have gone far beyond what Hubble achieved"



Ceres as a colour-enhanced map; adding colour to images can help scientists learn more about the materials on the surface

NASA/ESA/J. PARKER (SOUTHWEST RESEARCH INSTITUTE) P. THOMAS (CORNELL UNIVERSITY) L. MCFADDEN (UNIVERSITY OF MARYLAND COLLEGE PARK) AND M. MUTCHLER AND Z. LEVAY (STSCI), NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 3, ISTOCK, NASA, NASA/JPL-CALTECH X 6

THE EXPERT

Prof Ulrich Christensen, chairman of Dawn's Framing Camera science team

What can Dawn's Framing Camera tell us about Ceres?
The Framing Camera is the main instrument on the mission and its images provide a plethora of information. Ceres's overall shape can tell us something about its internal constitution and formation history. The abundance and shape of impact craters carries information on the age of the surface and the properties of the substratum – soft versus hard. The mineral composition of the surface can be constrained to some degree by the colour information obtained using the different filters, not very precisely, but together with other information certain compositions can be excluded or highly favoured.

How are targets for the camera selected?
At the earlier stages of the Ceres mission, when the spacecraft is not very close to Ceres (in the so-called survey orbit and the high-altitude mapping orbit), the aim is to image and map the whole surface of the planet and no selection of particular targets is necessary. However, for particularly interesting targets, such as the very bright spot, the observations can be adapted, for example, reducing the exposure times – so far it has been overexposed – or taking images of it in all available colour filters under different illumination conditions.

What are you personally hoping to study with the camera in the coming months?
My main expertise and interest is in the internal structure and constitution of Ceres. Here the precise shape, correlated with the irregularities of Ceres's gravity field that are obtained from small perturbations of Dawn's orbit, provides essential information. This will tell us whether or not Ceres is internally layered into an icy shell and a rocky and metallic core, and, with some uncertainty, how thick the shells are and what their densities are. I am also involved in the colour interpretation, which – for example – may provide clues on what the very bright spots on the surface are.

The two bright spots revealed by Dawn took astronomers by surprise

Christensen, the chairman of Dawn's Framing Camera science team. "In the case of Ceres expectations have probably not been as high as usual because from the very low resolution Hubble Space Telescope images it appeared that there is not much structure and contrast at the surface. The excitement grew when it became more and more clear that there are small but very bright spots on a surface that is otherwise quite dark and an intense discussion started on what they could be."

Beacons in the grey

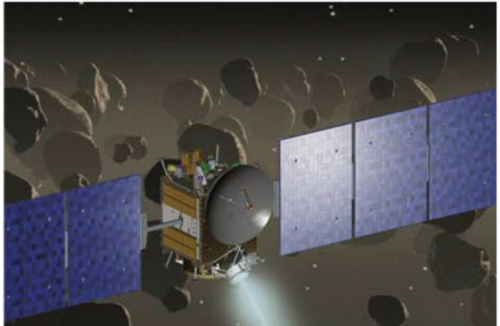
On the 25 February, NASA released an extraordinary image showing two of the bright spots seemingly 'shining' against the dull grey of Ceres's cratered surface. "We can think of no body in the Solar System on which we see such localised bright spots," says Carol Raymond, Dawn's deputy principal investigator. "We did expect that there would be some areas that were brighter than average – that was already seen in the Hubble data – but these spots are so localised and so very bright that they did take us by surprise."

Indeed it wasn't just the Dawn team who were wondering what their camera was seeing. Soon social media was awash with speculation about the mysterious features.

"The simplest interpretation would be that they are clean ice, which lies below a not too thick layer of exogenic 'cosmic dirt' at the surface, and which is exposed by geologically recent impacts," says Christensen. "However, in that case the white spots should be in depressions, and we have no good evidence for that. An even more exciting hypothesis is that they are either ice or perhaps salts that remain after water evaporates, brought to the surface by cryovolcanic activity."

Whatever the spots are, the simple truth is that we won't have to wait long before Dawn gets a closer look. "We will be in a better position to distinguish between different hypotheses when, in a few weeks, new images will come in with a resolution 2.5 times higher than what we have so far," Christensen adds.

Aside from the captivating bright spots, Dawn's approach images also showed a surface scarred by countless craters, including an enormous basin almost 300km wide. That might tell us something about the interior geology of the dwarf planet. "My first impression of the images of Ceres is that it looks pretty lumpy. In other words, it looks to have a large topographic range – probably too lumpy to be consistent with an ice shell over a liquid water ocean," says Dominic Fortes, an expert in icy moons at University College London who is not part of the Dawn team. "My inclination would be to say that Ceres, if it contains substantial amounts of ice, must be fairly cold and stiff to support that topography. On ▸



KEY DATES FOR DAWN

LAUNCH

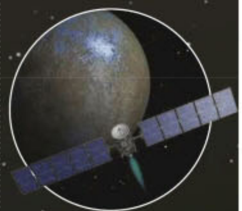
Dawn was launched on 27 September 2007 from the Cape Canaveral Air Force Station in Florida. In February 2009 it used the gravity of Mars to slingshot itself towards its first target, Vesta.

ARRIVAL AT VESTA

Ceres wasn't the only target the Dawn team had in their sights. In July 2011 the spacecraft arrived at Vesta, returning spectacular high-resolution images of its cratered, irregular form.

APPROACHING CERES

By early 2015 Dawn was getting ever nearer to Ceres. As it made its approach, the spacecraft's camera provided unprecedented new views of the surface and its enigmatic bright spots.



CERES ARRIVAL

Finally, on 6 March 2015, Dawn used one of its ion engines to enter orbit around the dwarf planet. Its initial orbit placed it at a height of around 61,000km above the surface of Ceres.

SURVEY AND MAPPING ORBITS

By early June 2015 Dawn should have entered its surveying orbit 4,400km above Ceres. Later in the year it will move closer to carry out even more detailed mapping of the surface.

MISSION END

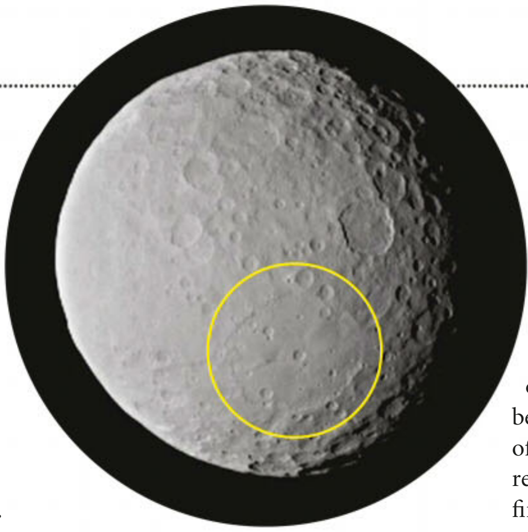
Dawn's primary mission is likely to come to an end in June 2016. The spacecraft also only has a finite amount of fuel aboard; when that's been used up it will lose its ability to orientate itself.

▸ the other hand, there seem to be some intriguingly smooth areas; quite what they are is anyone's guess – indeed it may be an illumination artefact."

With all the excitement of Dawn's tantalising approach images it's easy to forget that, at the time of writing, the probe hasn't even started its detailed surveying of Ceres. Since entering orbit on 6 March Dawn has returned few new images of the dwarf planet. There is, however, a reason for this, says Polanskey.

"The particular trajectory that optimised the delivery of the spacecraft to the first science orbit phase just happened to spend about a month on the dark side of Ceres," she says. "Any images taken during this time would not have contributed to better navigation. Collecting images takes time away from the spacecraft's main job of thrusting with the ion engines to get to its destination, so during the approach we only plan to acquire data when it is useful to the navigators."

For the researchers working on the Dawn mission, having their spacecraft orbiting Ceres will allow them to explore one of the most important processes in planetary science. "Ceres is a planetary building block that is a remnant from the very earliest period of Solar System history. As such it provides new data about how planets formed from the solar nebula of dust and gas," says Raymond. "Ultimately we want to know if and when conditions on Ceres could have been habitable, and extend our knowledge of its formation and evolution to understand better other protoplanets."



▲ Ceres as seen from 46,000km, revealing an enormous, 300km-wide basin

The missing ocean

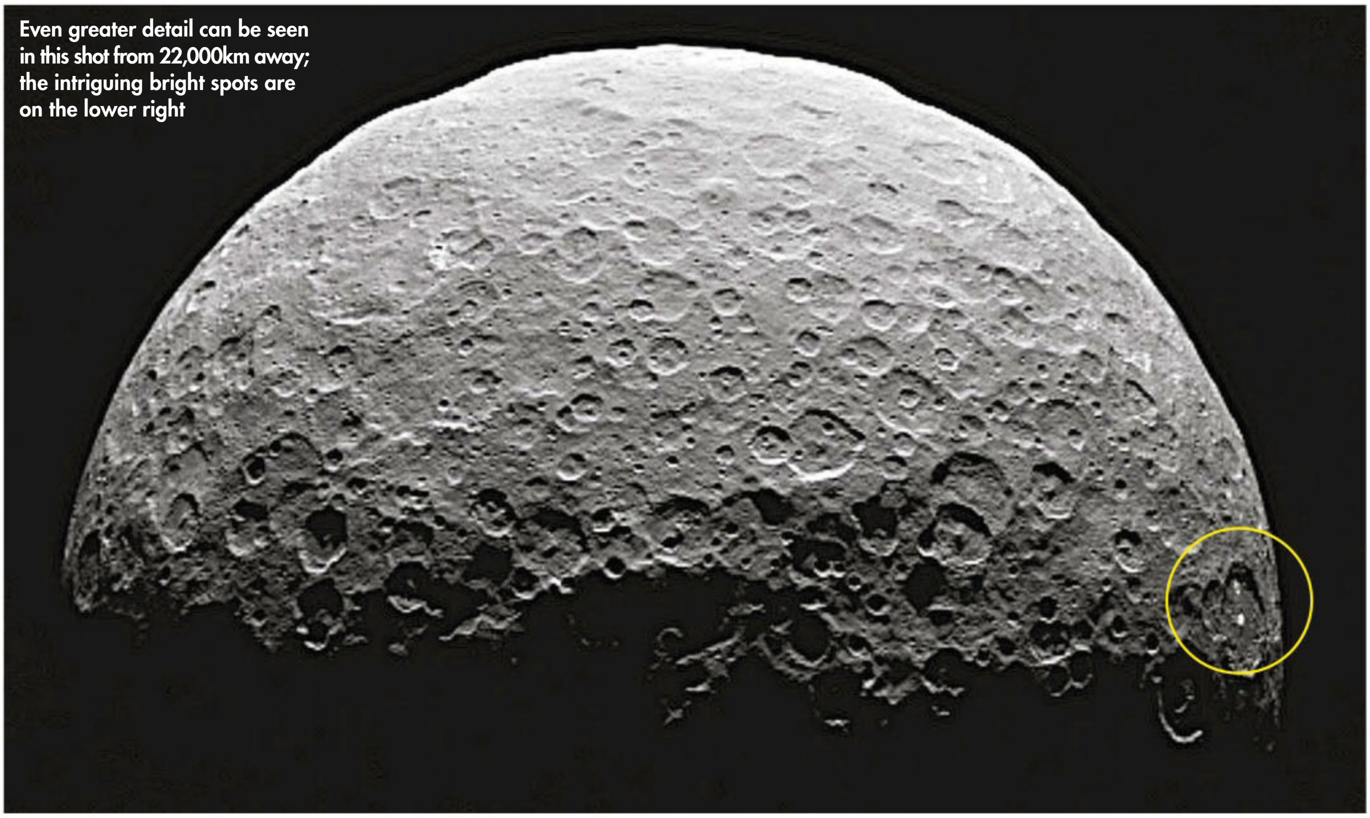
Perhaps the most intriguing thing about this little world sitting out in the asteroid belt is what may have once existed beneath its surface. "It is hard to avoid the conclusion that Ceres had a subsurface ocean," says Raymond. "Its low density indicates that its volatiles did not all escape. Its bulging shape indicates it has separated into a rocky core and an ice mantle. Given Ceres's size and assuming a modest amount of radioactive heating, thermal evolution models show that the interior was warm enough to support a liquid ocean for quite some time."

Dawn's next step will be to enter into a circular orbit around Ceres. From there it will inch nearer to the dwarf planet in stages, with the closest orbital phase beginning in December; that will see the spacecraft flying at just 375km above the surface. "Once we get into the first circular orbit at 13,500km altitude we will begin seeing Ceres at 20 times the resolution of Hubble, and we expect that even this resolution will be enough to draw some firm conclusions about the bright spots and the nature of Ceres's surface," explains Raymond. "However, this will only be a taste of the fantastic wealth of data that will be coming over the course of the coming 16 months of operations."

In fact, by the time you are reading this Dawn will hopefully be carrying out its survey orbit around Ceres. Will we know by then what the bright spots are, or will the dwarf planet throw up yet more surprises? "Busy times are ahead of us," says Christensen; given how Ceres has amazed scientists and the public alike in just these last few weeks, that's perhaps the only thing we can be certain of.

ABOUT THE WRITER

Will Gater (@willgater) is an astronomer and writer. He is the author of several books and presents live astronomy shows for Slooh.



Even greater detail can be seen in this shot from 22,000km away; the intriguing bright spots are on the lower right

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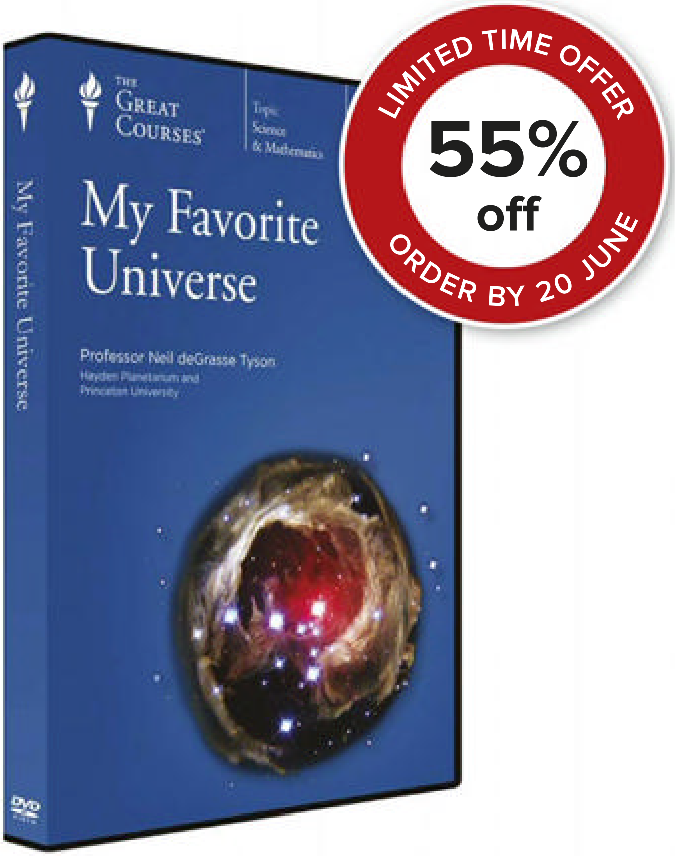

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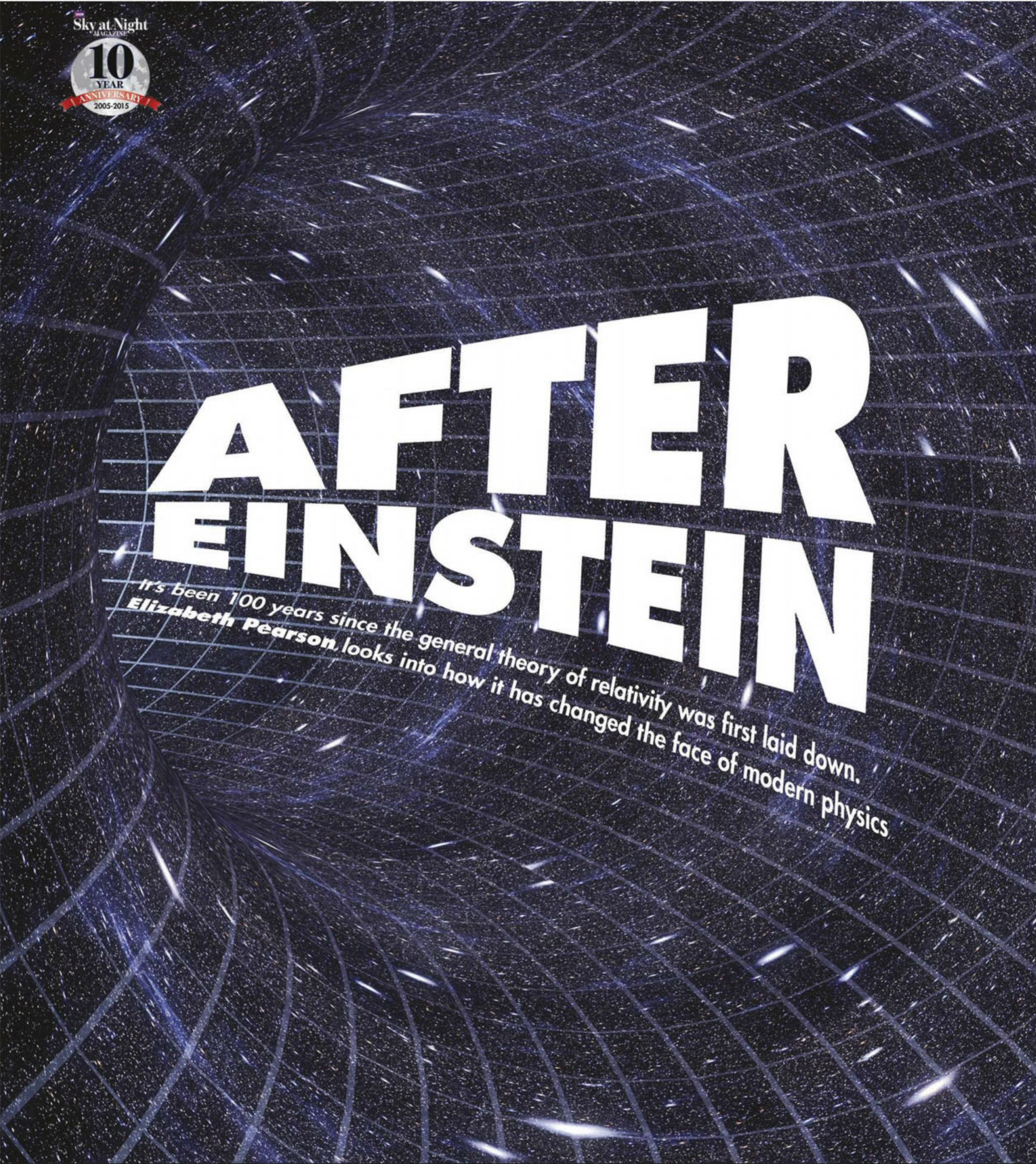


AFTER EINSTEIN

*It's been 100 years since the general theory of relativity was first laid down. **Elizabeth Pearson** looks into how it has changed the face of modern physics*

In November 1915 Albert Einstein was preparing to present what would go on to become one of most important sets of equations to have ever been put down on paper: his general theory of relativity.

General relativity was developed as an attempt to unify the forces of electromagnetism and gravity. It was a task that obsessed Einstein for more than eight years as he sought to include gravity in his already successful special theory of relativity.

Before general relativity was laid down Newton's Laws of gravity had reigned for more than two centuries, but something was lacking. The theory hinged on a mysterious and invisible force known as gravity that held the Universe together, but gave no real explanation as to what caused it or how it worked, only its effects. As technology advanced, new precise measurements were beginning to show the flaws. Observations didn't match up to theory, and by the beginning of the 1900s people were looking for a new explanation of gravity.

It was these problems that Einstein created relativity to fix. But his theory was so strange that even after definitive ▸

▸ proof had been provided it would take several years for general relativity to really gain a foothold. Once it had, however, it completely changed the way that we looked at our Universe and now, 100 years later, it underpins nearly all modern physics.

General relativity states that everything that has a mass, from atoms to galaxies, sits within a four-dimensional spacetime that is bent and shaped by objects as they travel through it. The larger the mass of an object, the more it distorts spacetime around it. These disturbances in the fabric of spacetime then go on to affect everything that moves through it, including light.

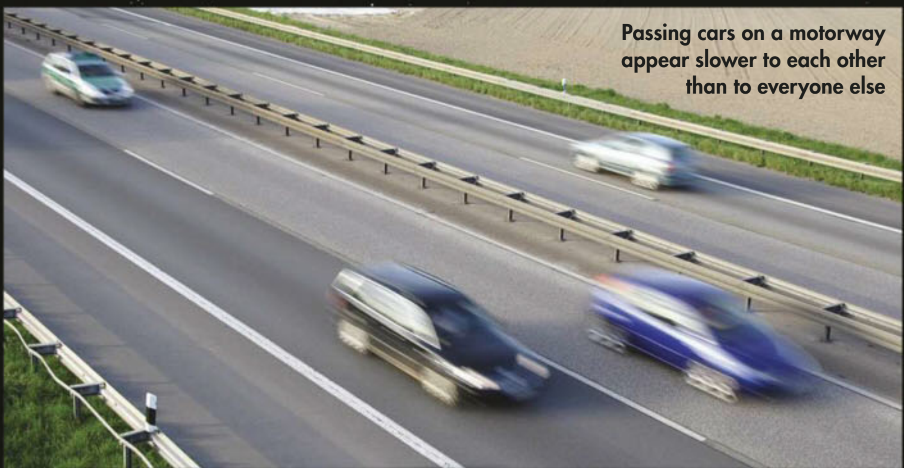
This idea provided the foundation for our understanding of black holes, gravitational lensing and gravitational waves. "General relativity is an extremely successful theory," says Abhay Ashetekar, director of the Institute for Gravitation and the Cosmos at Pennsylvania State University. "But it has limitations. At the very beginning of the Universe or inside a black hole, relativity predicts that physical limits become infinite and physics as we know it comes to an end. This is showing that the theory has been pushed beyond its validity. It's a signal that a new theory is needed."

Now attempts are being made to reconcile it with the other great theory of our Universe: quantum mechanics, the physics of nanoscopic scales where everything is made up of individual discrete units called quanta. But uniting these two conflicting systems is not straightforward. Where gravity deals in absolutes, where every action causes a known reaction, quantum mechanics gives only the probablity of something happening. Trying to mesh them into a theory of 'quantum gravity' has met with little success. The most well-known attempt to do so is string theory, which postulates that what we see as particles are actually vibrating one-dimensional strings of energy. Other theories, such as quantum loop gravity, attempt to quantise gravity, pixellating the fabric of spacetime into individual quanta so that if you could look at it up close you would see structure that isn't visible on a macroscopic scale.

WHAT'S SPECIAL **ABOUT RELATIVITY?**

Ten years before his general theory, Einstein published a paper on special relativity. This stated that no matter how fast you were travelling, the laws of physics remained the same within your own sphere of reference.

One of the key concepts was the universal speed limit of light. Before Einstein it was assumed that the speed of light changed relative to the observer. If you were moving relative to a light source, then this difference in speed would change the speed of light, in the same way that if you were driving on a motorway and overtook another vehicle, it would appear to be travelling slowly compared to you regardless of its actual speed.



Passing cars on a motorway appear slower to each other than to everyone else

What relativity states is that the speed of light remains fixed, no matter what the speed of the observer. Instead the fabric of spacetime changes to ensure the speed limit is kept. The 'special' part about this initial theory was that it only considered what happens with regard to objects moving at high velocity. When composing his general theory, Einstein took these ideas and played them out across the entire Universe, such as when objects are accelerating. This was important as he could then substitute out the effects of acceleration for those caused by gravity, giving him the framework that would go on to form the basis of most modern cosmology.

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String theory posits that the particles we see are 1D strings of energy

"General relativity absorbs gravitational fields into the very geometry of spacetime," says Ashetekar. "If that's true then the geometry of spacetime should be quantum mechanical. Spacetime itself should have fundamental building blocks. There should be atoms of geometry."

Testing falters

Unfortunately trying to observe these 'atoms of geometry' is currently beyond the realms of technological possibility. This is one of the fundamental problems experienced by those investigating quantum gravity. While it's possible to produce elegant simulations and equations to describe the Universe, proving them is exceptionally difficult.

There are teams at work trying to pick out the traces of quantum mechanics left behind in the very early Universe by observing, for instance, the cosmic microwave background. However, trying to test the theories directly requires a phenomenal amount of energy, far beyond what humankind is currently capable of producing.

But it is not uncommon for scientific theory to make predictions beyond the limits of what can be tested, only for technology to catch up later. This, notes Martin Hendry, professor of gravitation and astrophysics at the University of Glasgow, was the case for another phenomenon predicted by general relativity, gravitational waves.

"Gravitational waves are produced by astrophysical sources in the Universe moving through spacetime, when objects such as black holes and neutron stars collide and combine together. Then they spread out like ripples in a pond."

The search for these gravitational waves (or 'gravy waves' as they are known to those that study them) is a major focus of research today. They were proposed soon after Einstein's 1915 paper was published, but it has taken the intervening century for technology to catch up to the point that we might be able to find them.

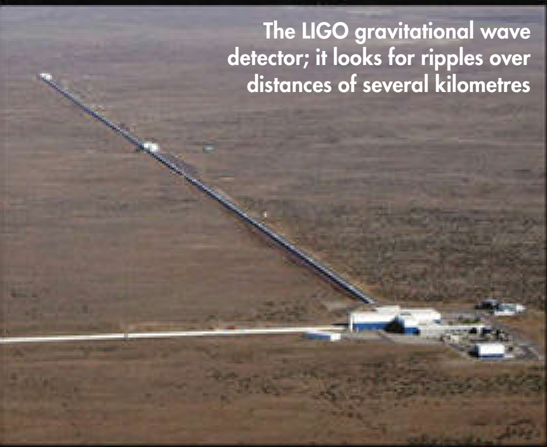
Today's detectors are huge, using lasers to accurately measure distances of several kilometres, searching for the tiny changes that would be caused by a gravitational wave passing through and stretching or shrinking spacetime. It's no easy task, as the changes being looked for are smaller than the size of an atom.

Luckily two of the biggest detectors, LIGO and VIGRO, are in the process of being upgraded. Perhaps then they will finally be able to record one; most likely caused by two massive bodies colliding.

"Up to now, these disturbances have been completely swamped by others due to all sorts of local noise sources," says Hendry. "But the prime candidate for astronomical signals that can be ►

"The search for gravitational waves is a major focus of research today"

When massive bodies such as black holes collide they send out ripples – these are gravitational waves



The LIGO gravitational wave detector; it looks for ripples over distances of several kilometres

▸ detected is the coalescence of compact binary systems."

When dense sources spiral into each other and merge together an enormous amount of gravitational energy is radiated off in the form of waves. These may just be large enough to be detected here on Earth. Though such waves have yet to be detected directly, there is already some indirect evidence for them.

"There is a neutron star binary system, the Hulse-Taylor binary, which is probably the most convincing piece of evidence we have that gravitational waves exist," says Hendry. "General relativity predicts that energy should radiate away in the form of gravitational waves, causing the orbits to shrink. The change in the orbital parameters of that binary system agrees beautifully with the predictions of general relativity."

Discarding the chaff

One of the biggest problems facing those running the detectors, however, is knowing what to look for.

"One of the interesting things about general relativity is that it's non-linear, you can't superimpose two gravitational fields," says Harvey Reall, professor of theoretical physics at the University of Cambridge. "This means you cannot simply add two gravitational fields together, say that of the Sun and Earth, and find out exactly what the end result would be.

Though there are many good approximations for weak gravitational fields, when the field is strong – as it would be around a black hole – combining the effects of two is nearly impossible to do directly. Instead researchers had to run computer simulations to get an estimate.

"Researchers started simulations of merging black holes in the 1970s," says Reall. "They could do one orbit before the code crashed. But in 2005, two teams finally managed to crack the problem. Now people routinely extract the gravitational waves emitted by black holes and neutron stars."

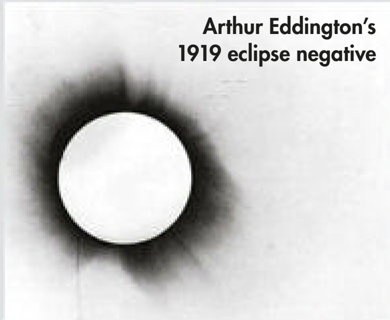
Knowing what gravitational waves might get emitted makes the job of picking out the signal from general noise much easier. With the next generation of detectors already being planned, it's hoped that gravitational waves will be detected within the next few decades.

"Once we know how to look at the Universe using gravitational waves, the hope is we'll see things that were completely undetected. It'll be a completely new way of doing astronomy," says Reall.

Gravitational waves will open up a new way of studying the cosmos, as relativity gave us a new framework to think about the world around us. One hundred years after Einstein first proposed his great theory, research teams all over the world are working with and developing his equations, coming up with questions no one had even thought to ask a century ago. Hopefully by the time the next centenary comes around we'll have at least some of the answers. Ⓢ

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University.

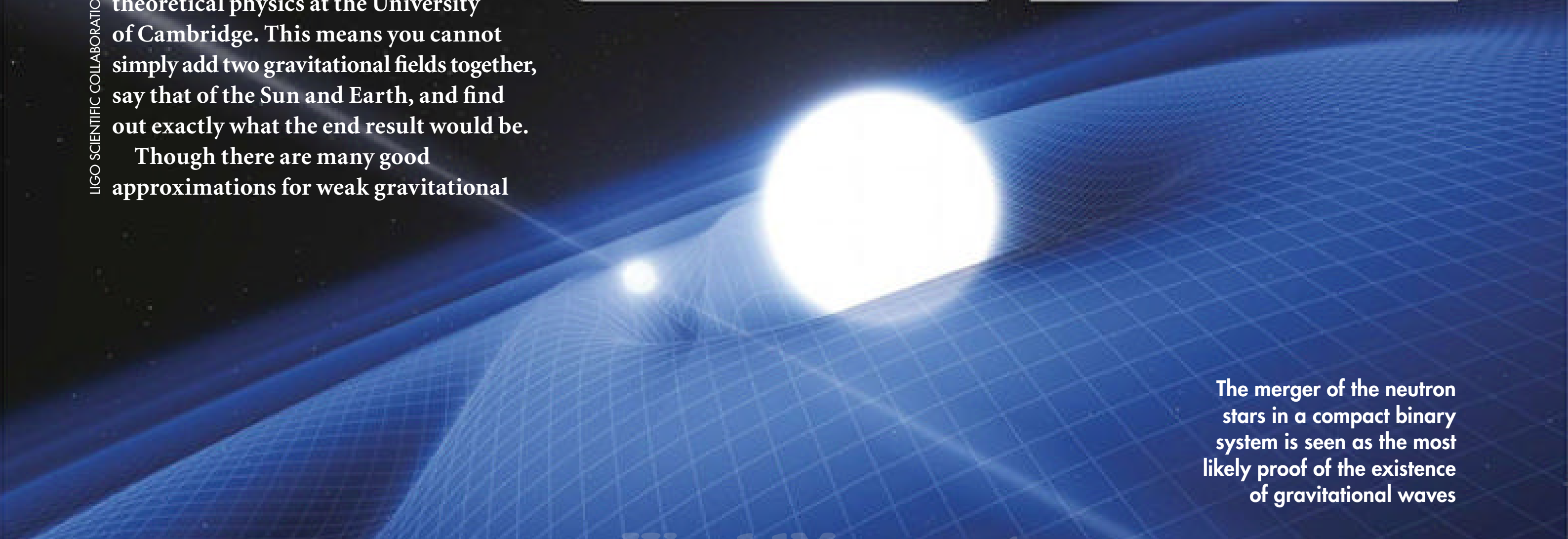


Arthur Eddington's 1919 eclipse negative

FINDING PROOF

Einstein's theories were revolutionary, but in order to be accepted they needed to be proved. The first major success of his theory came from explaining the precession in the perihelion of Mercury. The orientation of the planet's orbit moves by around 2° each century, which doesn't match up with what is predicted by Newtonian gravity. When Einstein applied his theory he explained that gravity was also being affected by the curvature of spacetime, causing the discrepancy. But the proof that would make Einstein a household name didn't come until 1919, when Sir Arthur Eddington went on an expedition to Brazil to observe a total solar eclipse. Without the glare of the Sun it would be possible to see the stars around our own. Relativity stated that the Sun's mass would bend the light from the stars, altering their position on the sky compared to earlier in the year when the Sun was on the opposite side of the planet. Eddington's observations confirmed this was the case.

The theory was tested further as technology has advanced. ESA's Gravity Probe A sent an extremely accurate clock into orbit, revealing that time passes slower in lower gravity as time dilation predicts. Its successor, Gravity Probe B, managed to accurately measure the curvature of spacetime caused by the planet's mass. Now these effects are so well known that GPS satellites have to periodically alter their internal clocks to prevent them from getting too far ahead of clocks on Earth.



The merger of the neutron stars in a compact binary system is seen as the most likely proof of the existence of gravitational waves

LIGO SCIENTIFIC COLLABORATION, ESO/L. CALÇADA

The Darwin Centre Wales

The Darwin Centre has its 21st birthday this year, celebrating over 2 decades of workshops, field trips, festivals, research, and fun.

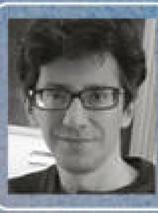
2015 also marks the 10th year of the core educational programme the Dragon LNG Darwin Experience. The programme sees thousands of young people take part in STEM related activities every year, raising confidence, understanding, and access to the world of science, technology, engineering, and mathematics.

The Darwin Experience is a partnership between the Darwin Centre, their core sponsors Dragon LNG, Pembrokeshire County Council, and Pembrokeshire College. darwincentre.com, Facebook, and Twitter.

THE SIX GREATEST MILESTONES IN RUSSIAN SPACE EXPLORATION

Anatoly Zak recounts how the USSR kickstarted the Space Race and paved the way for the ISS

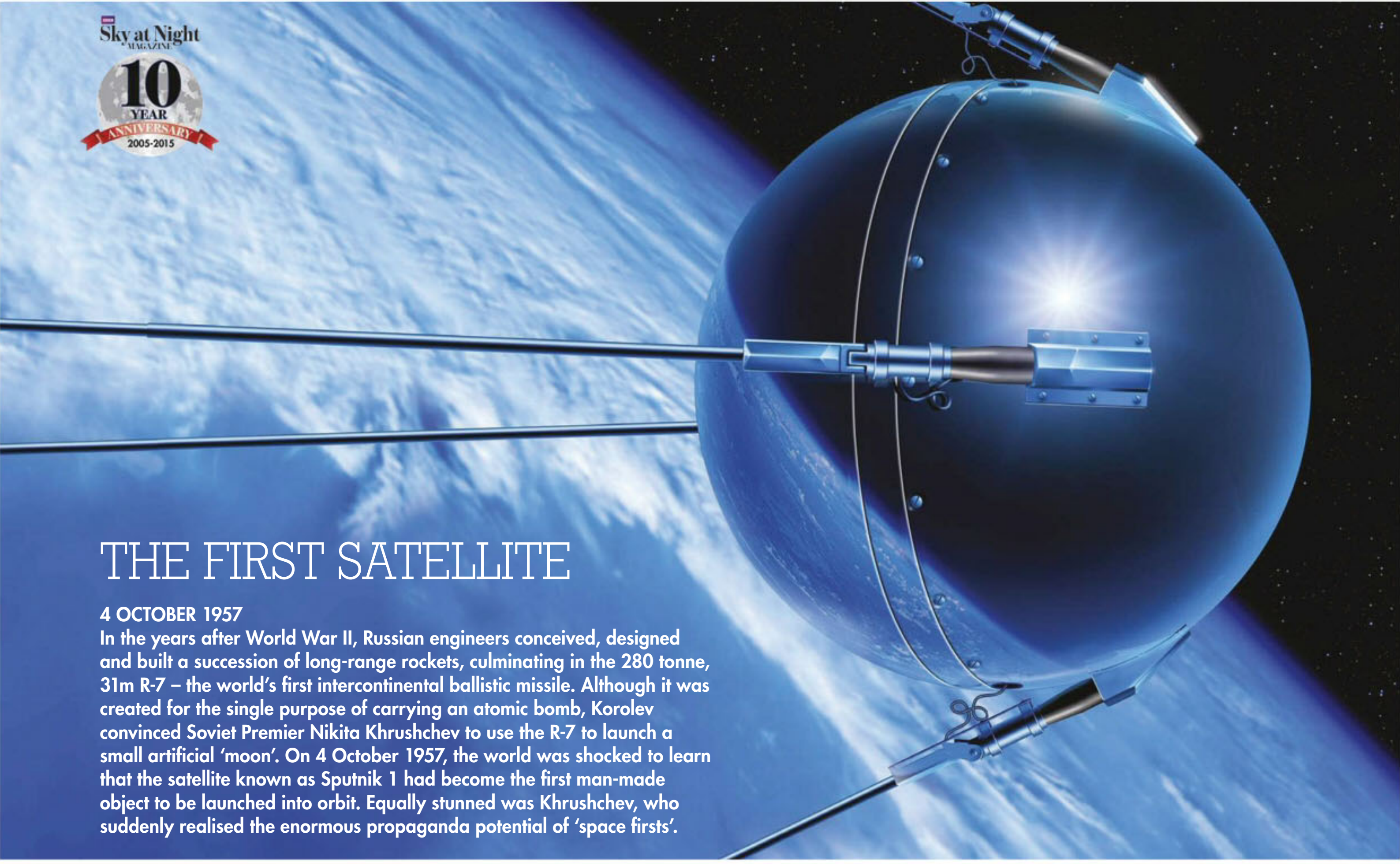
Soviet Russia was the birthplace of cosmonautics. It all started with schoolteacher Konstantin Tsiolkovsky, who dreamed about the conquest of space at the turn of the 20th century and inspired young enthusiasts to experiment with home-made rockets in the 1920s. Within a decade, those amateur efforts were taken over by the first professional research organisation in the field of jet propulsion, sponsored by the Red Army. As a result, when the USSR recovered German V2 ballistic missiles at the end of World War II, they went right into the hands capable engineers. Led by Sergei Korolev, they were determined to take the rocket legacy of the Third Reich on a shortcut to space. ▸



ABOUT THE WRITER

Anatoly Zak is a science writer who specialises in the history of space exploration. He is author of *Russia in space: The past explained, the future explored.*

Vostok 1 blasts off on 12 April 1961 with Soviet cosmonaut Yuri Gagarin aboard



THE FIRST SATELLITE

4 OCTOBER 1957

In the years after World War II, Russian engineers conceived, designed and built a succession of long-range rockets, culminating in the 280 tonne, 31m R-7 – the world's first intercontinental ballistic missile. Although it was created for the single purpose of carrying an atomic bomb, Korolev convinced Soviet Premier Nikita Khrushchev to use the R-7 to launch a small artificial 'moon'. On 4 October 1957, the world was shocked to learn that the satellite known as Sputnik 1 had become the first man-made object to be launched into orbit. Equally stunned was Khrushchev, who suddenly realised the enormous propaganda potential of 'space firsts'.

▽ YURI GAGARIN'S ORBIT OF EARTH

12 APRIL 1961

After the triumph of the Sputniks, Khrushchev needed little convincing to approve a long-term space programme. The development of the first piloted spacecraft, Vostok, had been initiated to beat the US Mercury project and was helped by the fact that the same ball-shaped capsule for the pilot could also be used to return spy photos from orbit for the Soviet military. After seven unmanned test launches, the young pilot Yuri Gagarin lifted off from a test site in Kazakhstan on 12 April 1961, becoming the first human in space. After a 90-minute journey around Earth, Vostok's braking engine pushed the capsule back into the atmosphere. Gagarin ejected and safely parachuted to land near the Volga River, a few hundred kilometres south of Moscow.

△ LAIKA'S ONE-WAY TRIP

3 NOVEMBER 1957

Basking in the political windfall of Sputnik 1, Khrushchev asked Korolev for another out of this world spectacular for the 40th anniversary of the 7 November revolution that brought the Bolsheviks to power. With a barely a month to prepare, Korolev's team quickly fashioned a 'biological satellite' out of a pressurised dog cabin previously used for stratospheric rocket flights. However, without the special heat shielding needed to survive re-entry into Earth's atmosphere, the satellite's only passenger – a female mongrel called Laika – had no return ticket. Laika probably died just few hours after reaching orbit on 3 November due to inadequate thermal control.

△ THE SOVIET LUNAR ROVERS

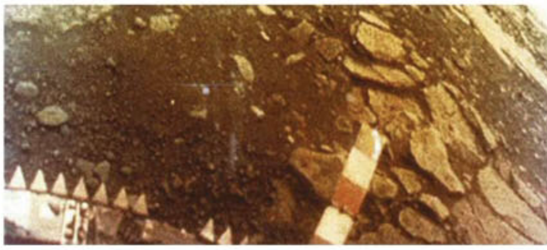
NOVEMBER 1970 AND JANUARY 1973

The Sputniks and Vostoks were credited with triggering the race to the Moon between the Soviet Union and the US. The White House correctly calculated that aiming for the lunar surface would push the USSR beyond its technical and financial capabilities, and sure enough the Soviets never came close to landing a man on the Moon. However, the USSR did succeed in sending a pair of eight-wheeled rovers, the Lunokhods, which crisscrossed the lunar surface in the early 1970s. Although originally conceived to taxi cosmonauts across lunar plains, the Lunokhods became a symbol of a cheaper robotic lunar exploration for Soviet propaganda. In the process, Soviet science benefitted too.

▽ THE VENERAS AT VENUS

DECEMBER 1970 TO MARCH 1982

At the same time that the Soviets were racing the Americans to the Moon, they were also sending unmanned robots to the planets of the Solar System. And while the majority of Soviet Mars probes did not survive the journey to the Red Planet, at Venus they achieved results that stand unmatched to this day. In December 1970, the egg-shaped Venera 7 lander reached the hellishly hot surface of Venus and stayed alive long enough to transmit 23 minutes of temperature data. Five years later the twin Venera 9 and Venera 10 landers sent back the first black and white images from the surface, and in 1982 Venera 12 and Venera 13 delivered the first and only glimpses of the Venusian surface in colour.



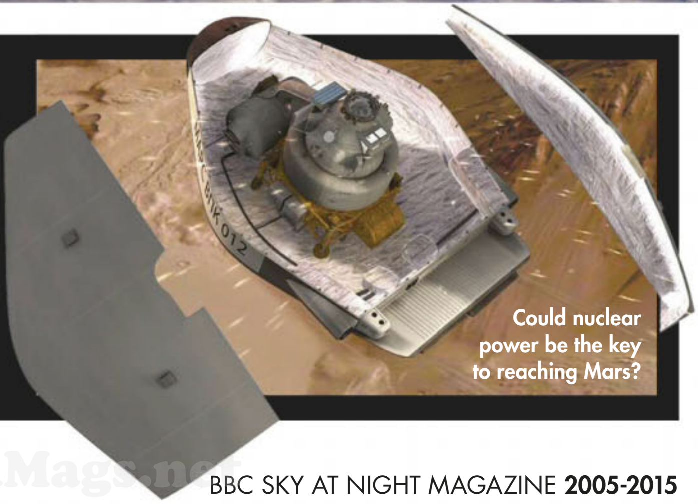
THE MIR SPACE STATION

FEBRUARY 1986 TO MARCH 2001

After the US landed men on the Moon, the USSR refocused its efforts onto the development of Earth-orbiting space stations. From 1971, nine space labs were fired into orbit under the Salyut series. In 1986, the USSR launched the first piece of a multi-modular space station named Mir. Its assembly continued until 1996, with six add-on modules attached to the original core unit. Permanently inhabited by changing shifts of cosmonauts, Mir hosted numerous foreign guests and even entire Space Shuttle crews, who made regular visits between 1995 and 1998. Long outliving the country that launched it, Mir was finally deorbited in 2001 after a record-breaking 15 years in space, paving the way for the International Space Station.

INTO THE FUTURE...

The Russian space programme continues forging ahead on various fronts. In cooperation with American, Canadian and Japanese colleagues, Russian cosmonauts live and work on board the International Space Station, which is scheduled to operate until at least 2024. Back on the ground, Russian engineers are working on a next-generation transport spacecraft, which will be able to fly beyond Earth orbit and into the vicinity of the Moon. New modules for a next-generation space station and a nuclear-powered space tug, which could eventually carry humans to Mars, are also under development in Russia. Ⓢ



Could nuclear power be the key to reaching Mars?

UK Retailer Guide

Find the right one for you: buy your telescope from a specialist retailer

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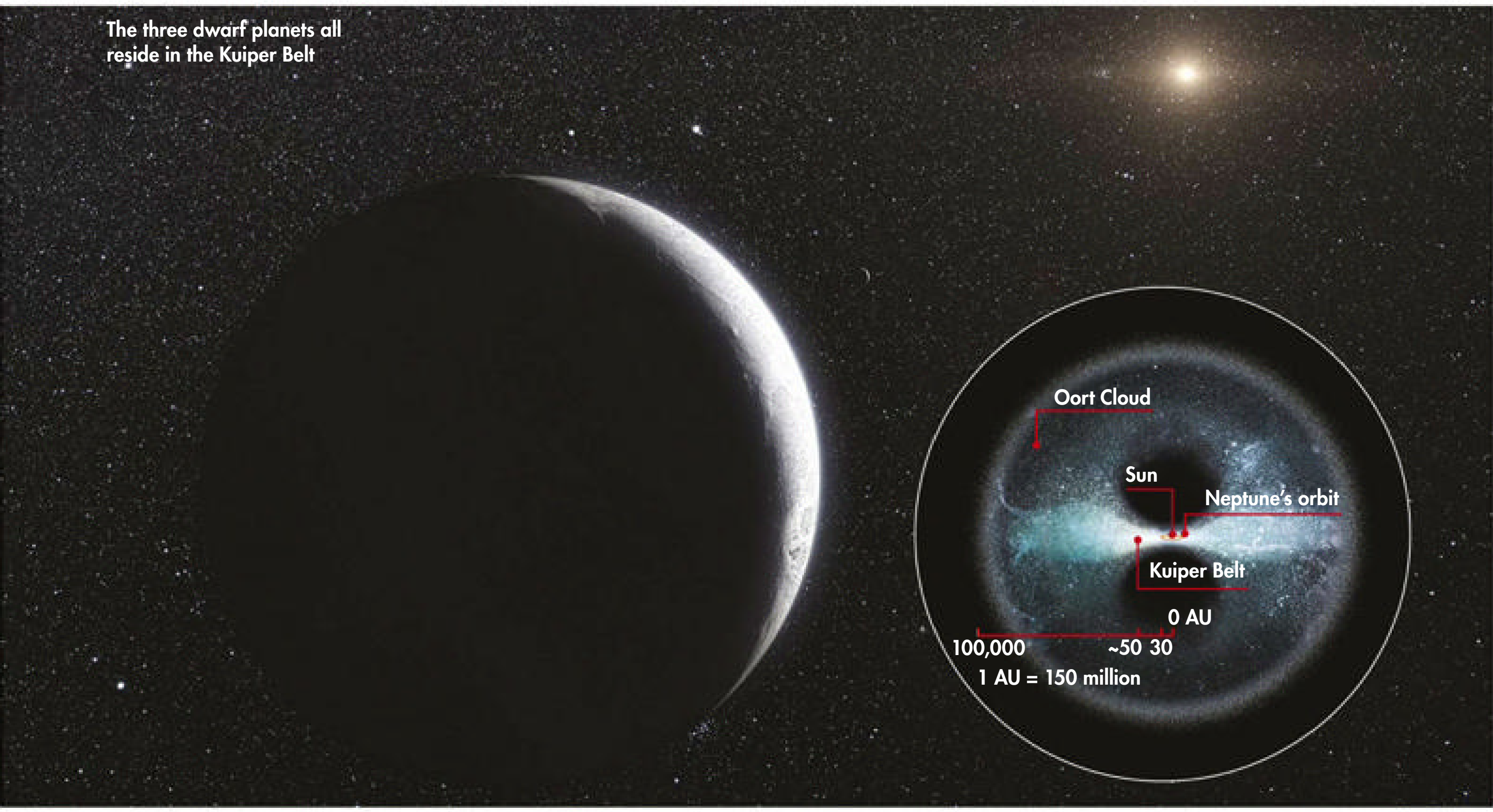
The Guide

The other dwarf planets

With **Paul Sutherland**

What exactly do we know about Eris, Haumea and Makemake?



The three dwarf planets all reside in the Kuiper Belt

With NASA's New Horizons probe fast closing in on Pluto, our knowledge of the outer reaches of the Solar System is set to be transformed. But in recent years we have already learned much about this distant zone.

It has become clear that Pluto – which was demoted from full planet to dwarf status in 2006 – is a kind of celestial gatekeeper to a vast region filled with countless icy bodies, known as Trans-Neptunian object; Pluto is a Trans-Neptunian objects itself. This region includes an inner zone known as the Kuiper Belt, the existence of which was suggested back in 1951. The first object within it other than Pluto was detected in 1992; today it is thought to hold hundreds of thousands of bodies.

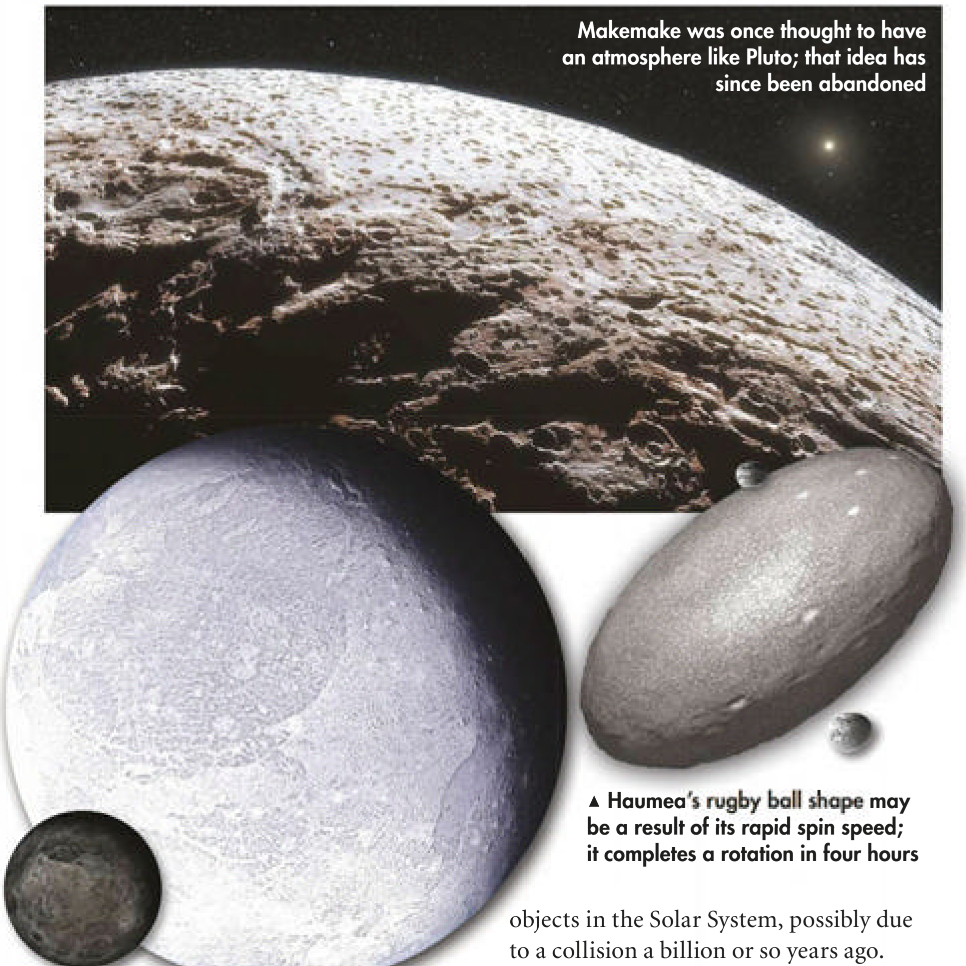
The zone has since been found to be home to three more dwarf planets – Eris, Haumea and Makemake. Like Pluto they orbit the Sun and are big enough to have achieved hydrostatic equilibrium (which in most cases means they are nearly spherical) but not cleared their orbits. One other body closer to home has also been classified as a dwarf planet – Ceres in the asteroid belt, which is currently being examined in detail by NASA's Dawn probe.

The far-flung pantheon

Eris was the first new world discovered beyond Pluto, spotted in 2003 during a survey led by Prof Mike Brown of the California Institute of Technology and confirmed in 2005. It is thought to be similar in size to 2,300km-wide Pluto and its discovery kicked off the debate over Pluto's own status. Eris has a highly inclined and elongated orbit, completed once every 557 years, that carries it from within Pluto's orbit to a distance twice as far away, far beyond the Kuiper Belt. Rocky Eris even has an atmosphere, but it freezes and collapses when it is at its most distant from the Sun, thawing again when it moves further in.

Originally labelled 2003 UB313, but dubbed Xena after TV's warrior princess, Eris was eventually named after the Greek goddess of chaos, strife and discord. Observations revealed that it has a satellite of its own, now named Dysnomia, after mythological Eris's daughter, the goddess of lawlessness. Scientists used Dysnomia's 16-day orbit to gauge Eris's size.

ESO/L. CALCADA, MARK GARLICK/SCIENCE PHOTO LIBRARY, ESO/L. CALCADA AND NICK RISINGER X 2, NASA/ESA/AND M. SHOWALTER (SETI INSTITUTE)



Makemake was once thought to have an atmosphere like Pluto; that idea has since been abandoned

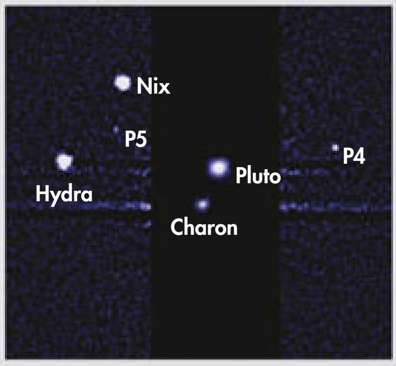
▲ Haumea's rugby ball shape may be a result of its rapid spin speed; it completes a rotation in four hours

▲ Eris and Dysnomia; it was the discovery of Eris that first called Pluto's status into question

COULD THERE BE MORE **DWARFS OUT THERE?**

Though there are five recognised dwarf planets, Prof Mike Brown of the California Institute of Technology believes there are dozens more in the Kuiper Belt that have not yet been classified. Some of the potentials have already been named – among their ranks are Quaoar, Sedna, Orcus and Salacia. "We know of probably a hundred and I think there are many more to be found, much further away," he says. "Each one of them is a unique world in an interesting way, and each one of them contains just a little bit of the history of the Solar System. When you look at Pluto you see this system with multiple moons and that tells you a story of a giant impact four billion years ago.

"Both Pluto and Eris have held on to atmospheres for their entire existence but when you get a little bit smaller such as Makemake you lose your atmosphere," he adds. "All of these objects are helping us understand the context of what we'll be learning in detail about Pluto."



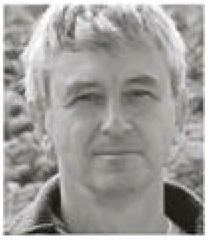
▲ Pluto's numerous moons may be a sign of a collision with another dwarf planet

Haumea's discovery was announced in 2005, having been noticed independently by both Brown and a group of astronomers at the Sierra Nevada Observatory in 2003. Though it is also similar in size to Pluto, Haumea is shaped more like a rugby ball. This rock and ice world has a less extreme orbit than Eris, varying from 7.7 billion km at its farthest to 5.1 billion km when closest to the Sun, which it orbits once every 282 years. It spins once in just under four hours, making it one of the fastest rotating objects in the Solar System, possibly due to a collision a billion or so years ago. Haumea also has a mysterious red blotch on its surface that may indicate an area richer in minerals and organic materials. The dwarf planet, first designated 2003 EL61 and nicknamed Santa, is now named after the Hawaiian goddess of childbirth and fertility. Its two small moons are named Namaka and Hi'iaka after Haumea's own spirit daughters.

Makemake was another find by Brown's team, discovered in March 2005 from the Palomar Observatory in California, and initially labelled 205 FY9. It orbits within the Kuiper Belt at an average distance from the Sun of 6.7 billion km, taking 310 years to complete one orbit. Makemake's size is not precisely known, but it is thought to be around two-thirds that of Pluto. Its rocky surface is covered with frozen ethane, methane and nitrogen, but it has no atmosphere and no known moons. Initially nicknamed Easterbunny, this dwarf planet's official name is that of the god of fertility for the Rapanui people who inhabited Easter Island in the Pacific Ocean. Ⓢ

Paul Sutherland is a space journalist and science writer

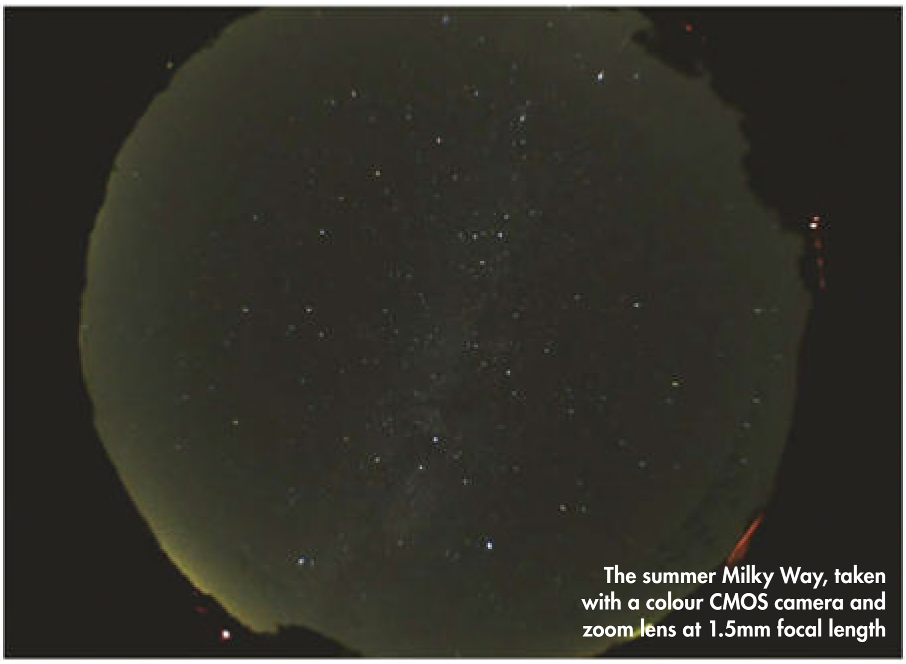
RELATIVE SIZES OF THE DWARF PLANETS



How to
Make a simple all-sky camera

With **Martin Lewis**

Learn how to record timelapses and meteor trails overnight



The summer Milky Way, taken with a colour CMOS camera and zoom lens at 1.5mm focal length

The winter sky taken with a monochrome CMOS camera and fixed focal length 1.55mm lens

TOOLS AND MATERIALS

CAMERA
A colour or monochrome digital video camera with 1/3-inch or larger chip and CS-mount thread at front. Suitable models include the ZWO ASI120 MM/MC, Celestron NexImage Burst, Celestron Skyris 132 (all CMOS 1280x960 pixels) and the DMK 31AU03.AS (CCD 1024x768 pixels).

FISHEYE LENS
A suitable C- or CS-mount 180° fisheye lens. Suitable models include the Rainbow L163VCS 1.6-3.4mm, Arecont Vision infrared-corrected 1.55mm and Fujinon YV2.2x1.4A-2 1.4-3.1mm.

HARDWARE
Two-inch dew heater band, tripod, laptop and connecting cables.

SOFTWARE
FireCapture (**http://firecapture.wonderplanets.de**) and PIPP (**https://sites.google.com/site/astropipp**)

An all-sky camera is an ideal tool for capturing the majesty of the celestial sphere turning silently overhead, and this month we're going to explain how you can make one of your own. With it you can make timelapse videos that reveal the movement of the stars as well as record bright meteors and satellites. Generally speaking, the all-sky cameras available to buy are contained within a weatherproof enclosure with a clear plastic dome, the camera inside fitted with a 180° fisheye lens pointing upwards. The camera is linked to a computer to record images of the sky every few seconds and the resulting video is processed later to make a timelapse movie.

The complicated part of this arrangement, if you want to have a go at building one yourself, is the enclosure. Consideration needs to be given to full weatherproofing and heaters need to be fitted inside the dome to keep it dew free. We're going to simplify ours by dispensing with the enclosure completely. So long as you know it is definitely not going to rain during the night, you can still take great

ALL PICTURES: MARTIN LEWIS

all-sky videos without it. All you need then is a suitable camera with a 180° fisheye lens wrapped with a dew heater band to stop the front glass dewing up.

You want a high-sensitivity digital video camera, the type sold for Solar System imaging. The limiting factor here is the size of the image produced, as the range of suitable fisheye lenses available tend to require camera chips with a height of around 4mm or larger. Although that excludes cameras with 1/4-inch chips, the newer generation of cheaper 1/3-inch CMOS chip Solar System imagers are ideal: these chips are 3.6x4.8mm in size. Various fisheye lenses can be used with these cameras. Some are zoom lenses and generally need to be on the widest field setting, while others have a short and fixed focal length.

Mono or colour?

If you use a colour camera at the heart of your setup you will record the hues of the brighter stars and the colour of the sky, especially at dusk and dawn, but also pick up the distinct glow of light pollution if it is present. For a monochrome camera, light pollution won't be so obvious and you can also use shorter exposures or lower the gain setting, as the absence of the colour filters will let more light onto the imaging chip. Monochrome is the best choice for meteor detection, as you want the camera to be as sensitive as possible to pick up their fleeting trails.

When choosing a site for your camera, look for somewhere that offers the least obstructed view of the sky. A consideration here is the length of your cables: you will need a 12V power cable for the dew heater and also a USB cable to connect your laptop, and the longer these are the easier it will be to store them somewhere safe and dry during the night while the camera does its work. You also need to think about your laptop's power usage. Will its battery last the whole night without additional power?

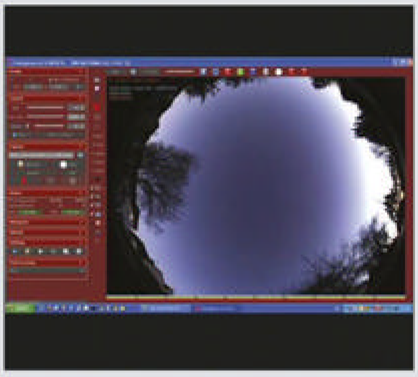
Once set up and recording, your camera should capture the night sky as you sleep. With luck, in the morning you should have a video sequence you can process, compressing the whole night into a couple of minutes, speeding up the movement of the heavens by several hundred times and making a fascinating record of the sky. Many amateurs add music to their videos to make them even more mesmerising, then post them on YouTube or Vimeo. S

Martin Lewis is a keen astronomer and regular *First Light* reviewer

STEP-BY-STEP GUIDE

STEP 1

The first time you set up, do it before darkness falls. Start by attaching a fisheye lens to your camera and then fixing them both to a tripod so that the lens points to the zenith. Connect the camera to your laptop with a USB cable.



STEP 2

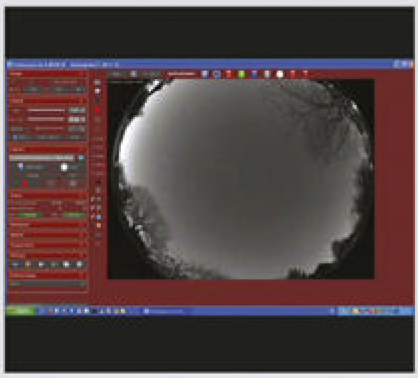
Use capture software such as the freeware FireCapture to preview the daytime scene on your laptop. Set the aperture at maximum, then adjust the focal length and focus to give a sharp 180° field that just spills over the edge of the frame.

STEP 3

There's nothing more to be done until it is dark. Once the stars are out, maximise the gain to reduce the exposure time. Then pick a bright star at a low altitude, zoom in and adjust the focus. Avoid using a star overhead as lens errors are more noticeable at lower altitudes.

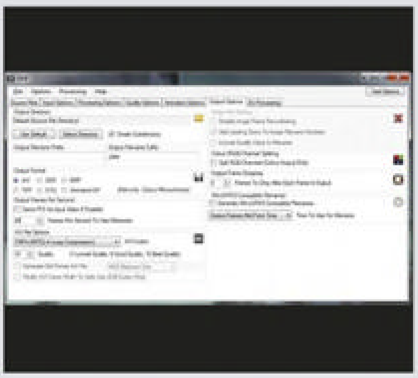
STEP 4

Without altering the focus, add a dew band around the top of the lens and turn it on; this will keep your optics dew-free all night. You also need to consider how you will power the heater (and your laptop) through the night, especially once the nights start to draw in.



STEP 5

Drop the gain to 50 per cent and alter the exposure time so that the sky background on preview is moderately dark but not black. Cap the lens and take a dark frame to eliminate any bright pixels. Set the video length to run until dawn and hit record.



STEP 6

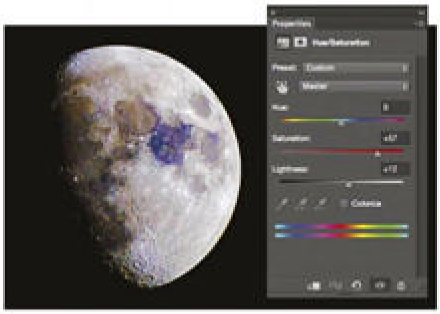
Use the freeware Planetary Imaging PreProcessor (PIPP) to alter the frame rate of the resulting video so it plays back in a few minutes and movement is massively speeded up. Save it in the mpg4 format to make the video a manageable size.

Image processing

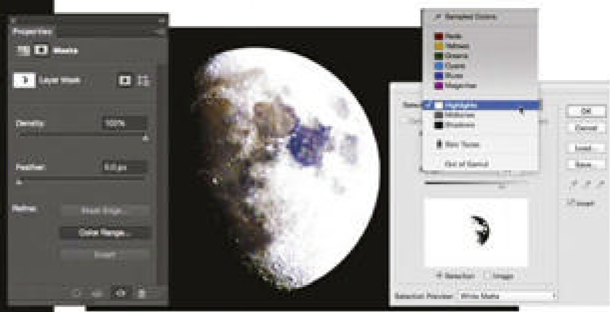
Colour saturating the Moon

With **Ian Evenden**

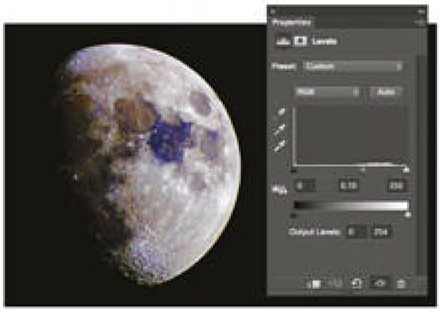
Our finished image is far more colourful than the Moon appears through an eyepiece



▲ Pushing up the colour saturation levels reveals purple and orange hues in the lunar maria



▲ Masking the brighter uplands prevents them from being altered by Hue/Saturation tweaks



▲ Use a Levels adjustment layer to darken the uplands for a more balanced composition

While it's not uncommon to think of the night sky as being essentially monochrome, white stars on a black canvas, in truth there is a lot of colour to be found in the cosmos. And it can be used to add detail and interest to your astro images.

We're not talking about the false colours here, but bringing out the natural colours in images of Solar System bodies taken with an ordinary unmodified DSLR. We've used Photoshop CC 2014 in this tutorial, but you could do the same thing in Photoshop Elements or GIMP.

Taking a picture of our old friend the Moon often leads to a very white body on a very black background, thanks to the brightness difference between the two. The subtle use of colour can bring out detail in the Moon's craters and emphasise the difference between the higher and lower areas without adding more black and white contrast.

Unfortunately, you can't just raise the colour saturation in the image – doing this leaves it looking extremely artificial. If you want to try it, in Photoshop click **Image** > **Adjustments** > **Hue/Saturation** and slide the Saturation slider all the way to the right. The result isn't very nice.

It's far better to apply Hue/Saturation as an adjustment layer, as you have more control over the effect. Do this by clicking **Layer** > **New Adjustment Layer** > **Hue/Saturation**. The Hue/Saturation Properties palette will open, and you can slide the Saturation slider to the right until you're happy with the colours in the darker parts of the Moon.

We only want the effect to be applied to the dark areas, as that's where the colour is. Click the Masks tab at the top of the palette and select Layer Mask. You can then use the Colour Range slider to mask off the bright lunar uplands. We used the dropper to sample a light spot and turned the Fuzziness up to about 130 to get a good range of highlights selected rather than just the sampled colour. You could also select Highlights from the menu at the top of the palette to get a similar effect.

Now these areas are masked, the Hue/Saturation adjustment won't affect them, and they stay white while the Moon's seas show off their purple and orange hues. This process is known as creating a Layer Mask, and is one of Photoshop's most powerful tools.

On our image, the Moon's uplands are still too bright, so we can apply another adjustment layer, this time for Levels (**Layer** > **New Adjustment Layer** > **Levels**), in exactly the same way. We used it to darken off the bright areas, again using a layer mask. Save the file as a layered PSD; that way you can come back to it in the future to make tweaks. Click **Layer** > **Flatten Image** to merge the layers and then save as a JPEG to finish the shot.

Ian Evenden is a journalist working in the fields of science, tech and photography

Scope DOCTOR

With **Steve Richards**

Our resident equipment specialist cures your optical ailments and technical maladies

STEVE'S TOP TIP

How do I use a star chart?

Star charts are your guide to the visible Universe but to use them you must first know where north is, and a compass is invaluable here. It takes some getting used to, but to match your chart to the sky you'll also need to hold it upside down and view it from underneath, with the chart's top facing north. Bright stars, which are shown larger than dimmer stars, are your 'signposts' to the objects you want to find. Choose a bright star on the chart near your chosen object and then locate it in the sky as a pointer to the object you want to observe.

How can I collimate my Sky-Watcher 200P f/5 Newtonian with an Altair laser collimator and a 2-inch centring kit?

ROBERT HOWELLS

The Sky-Watcher 200P is a popular telescope but, like all Newtonian reflectors, it requires regular collimation to get the best views. A collimating cap and a Cheshire collimator can be used to carry out this task. Alternatively, a laser collimator can also be used with two caveats: first, the collimator itself must be accurately collimated; and second, the collimator must be accurately centred in the focuser. The centring issue is resolved by using a centring kit. Calibrating the collimator can be done by rotating it in a V-shaped block while watching for any deviation from a fixed point on a wall about 6m away and adjusting the three grub screws in the body until there is zero deviation with a full 360° rotation.

However, there is another way of using a laser collimator that obviates any issues with the collimator itself. That is to couple it to a standard Barlow lens to produce a diverging beam of light instead of the normal, narrow laser beam. Place a white disc with a hole in its centre in the end of the Barlow lens. If you centre the shadow of the primary mirror's centre spot on the hole in the disc you will achieve a most accurate collimation of the primary mirror and this is the result you should rely on.

One option is to couple a laser collimator with a Barlow lens

I want to upgrade from my Sky-Watcher 200P so I can view planets, but still use my EQ5 mount. Would a Sky-Watcher Skymax 180 Maksutov be suitable?

RAYMOND COLLINS

A Sky-Watcher 150 Maksutov would be a better choice with an EQ5 mount

The best views of planets are afforded by long focal length telescopes as these give the highest magnification with any given eyepiece. You say you have a Sky-Watcher 200P reflector and an EQ5 mount, and that you would like to continue using this mount. Taking, say, a 10mm eyepiece, the magnification with the 200P would be 100x. The same eyepiece with the Sky-Watcher Skymax 180 Maksutov would yield a magnification of 270x. On the face of it, this would be excellent, but at this focal length and weight, the EQ5 would be quite challenged. A better choice, allowing you to retain your existing EQ5 mount, would be the Sky-Watcher Skymax 150 Maksutov. It would yield a magnification of 180x with the same eyepiece and the reduced weight makes it more suitable for your mount.

STEVE RICHARDS, PAUL WHITFIELD

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

BBC Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★☆ Very good
★★★☆☆ Good
★★☆☆☆ Average
★☆☆☆☆ Poor/Avoid

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90

This 16-inch truss tube Dobsonian is a smart update to a classic

This month's reviews

First light

Find out more about how we review equipment at: **www.skyatnightmagazine.com/scoring-categories**

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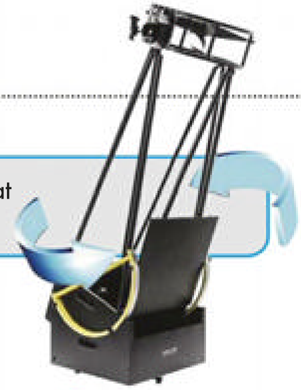
FIRST **light**



See an interactive 360° model of this scope at
www.skyatnightmagazine.com/ES16dob

Explore Scientific 16-inch truss tube Dobsonian

A light and compact Dobsonian that offers excellent optical performance

WORDS: STEVE COLLINGWOOD

VITAL STATS

- **Price** £1,664
- **Aperture** 406mm (16 inches)
- **Focal ratio** f/4.5
- **Focuser** 2-inch rack and pinion
- **Extras** Red-dot finder, secondary shroud, extension tube, primary collimation tool, 2- to 1.25-inch adaptor, battery holder
- **Weight** 38.4kg
- **Supplier** Telescope House
- **www.**telescopehouse.com
- **Tel** 01342 837908

WWW.THESECRETSTUDIO.NET X 5, STEVE COLLINGWOOD

Dobsonians remain a firm favourite with amateur astronomers seeking manageable and affordable large aperture telescopes. Though the simple altaz design of the Dobsonian mount has seen many refinements over the years, at its heart it is still an incredible piece of engineering.

This 16-inch truss tube offering from Explore Scientific is shipped in one box, with the rocker and mirror box pre-assembled and the other components ready to fit together by way of thumbscrews. While many commercial Dobsonians use rolled steel tubes and wooden rocker boxes, for this instrument they have been constructed from aluminium. The low-profile square design of the rocker and mirror boxes allows for a very strong and remarkably efficient system indeed. This is great if you want to travel to a darker location for a night's observing or have limited storage space.

The 16-inch primary mirror is made from BK-7 glass and has a focal length of 1,826mm, giving a focal ratio of f/4.5 –a short focal length for its size. The dual-speed 1:10 rack and pinion focuser is well made and can easily support heavier eyepieces. The unit felt very responsive with no image shift in use with a range of eyepieces. An extension for the drawtube is supplied.

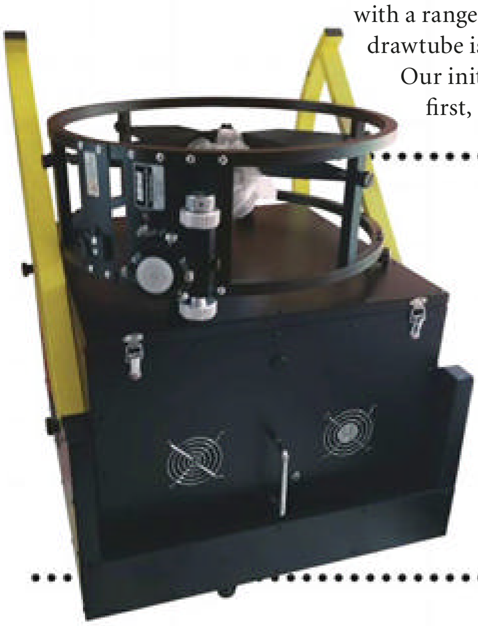
Our initial assembly progressed slowly at first, as some of the internal threads were poorly cut on our review scope, but once rectified we were able to put the telescope together with relative ease. The instrument has clearly been designed so it can be assembled by one person. Although we found this a little tricky at first, after a couple of times it was no trouble at all.

SKY SAYS...
With a 30mm eyepiece we were greeted with a wonderfully rich view of the Orion Nebula

We took the telescope out under the night sky with our own eyepieces, as none are supplied out of the box. Allowing the optics to reach ambient temperature for optimum performance can often take quite a while with larger optics, but the in-built cooling fans allowed the telescope to cool down sufficiently in less than 30 minutes. These fans are powered by eight D batteries (not supplied); their battery box can be strapped to the body of the telescope.

Unusual collimation

Collimation out of the box was close, but did need minor adjustment. Aligning the optics only took a matter of minutes. Primary mirror adjustments are made from the front of the mirror using the supplied long-reach collimation tool. Care needed to be taken to avoid touching the mirror's surface, but aside from that this method proved remarkably quick and effective. Secondary adjustments are made with large thumbscrews located behind the secondary mirror mount and, while unusual, they worked extremely well, ▸



EASY TO PUT UP, EASY TO TAKE DOWN

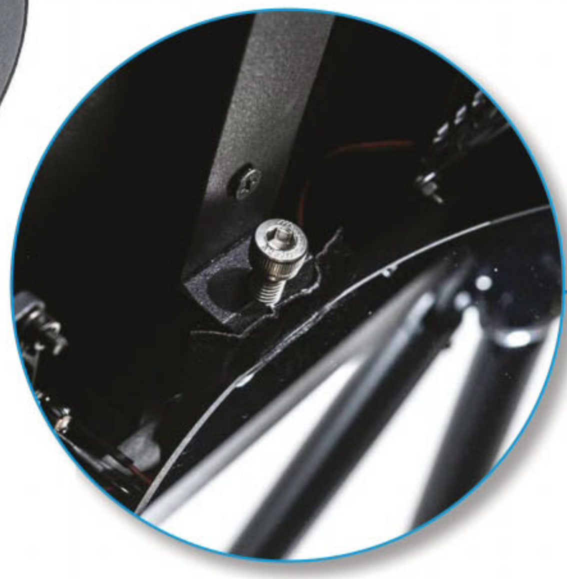
Larger aperture Dobsonian telescopes can be difficult to manage in terms of assembly, storage and transport, but this instrument is amazingly compact and portable for its class.

Its mirror box footprint of 55x55cm is tiny in comparison to many other 16-inch Dobsonians. We found that it could be easily carried through doors, and would even sit on the back seat of many cars. The box also has a hinged lid, ensuring that the mirror inside is protected when stored.

The low-profile head assembly is constructed from the same aluminium profile as the mirror box and rocker box, so is exceptionally light and easy to handle. We found that even after transporting and assembling the telescope several times, the optics required only minor adjustment. Throughout its design and construction, practicality seems to be the key. Lightweight materials coupled with basic construction techniques have really made the telescope very usable indeed.

FOCUSER

The supplied 2-inch rack and pinion focuser has a 1:10 reduction for fine focus. The drawtube can also unscrew to accommodate the supplied extension barrel.



PRIMARY COLLIMATION

Adjustments to the alignment of the primary mirror are made from the front of the mirror cell rather than behind it. This enables accurate collimation to be achieved more quickly, and without having to step away from the eyepiece. Doing this requires a special tool, which is supplied.

SECONDARY COLLIMATION

No tools are needed to collimate the secondary mirror. Adjustments are made via thumbscrews located behind the assembly, rather than the traditional point of directly above. This innovative approach allows easy access while reducing the risk of anything falling onto the primary mirror.

FIRST **light**

SKY SAYS...
Now add these:

1. Explore Scientific 24mm 82° 2-inch eyepiece

2. Explore Scientific 2-inch UHC filter

3. Revelation deluxe laser collimator

ALTITUDE WHEELS

The large altitude wheels proved to be really useful. Making smcll movements at high magnification can be difficult with telescopes of this size, but the larger diameter trunnions not only provide a smooth and positive feel but also aid balance when using a range of eyepieces.

COOLING FANS

The mirror box houses two battery operated fans: one 'pushes' cold air into the mirror box and across the surface of the mirror, while the other 'pulls' warm air out. The fans were quiet and effective in operation.

▸ enabling the whole operation to be carried out while still at the eyepiece.

Once cooled and collimated, we aimed the telescope at the Orion Nebula, M42. With a 30mm eyepiece we were greeted with a wonderfully rich view of the nebula and the stars in the centre. We then increased the magnification and moved on to Jupiter, revealing plenty of contrast and detail on the bright planet. Framed by the four Galilean moons, Jupiter was an impressive sight even though seeing conditions were relatively poor. However, we did find accurately sighting the telescope quite tricky, as the supplied red-dot finder was not very sturdy. Once a target was centred, the large wheels and base-bearing surface ensured a positive movement, enabling smooth and accurate tracking and good balance.

Overall this instrument was a pleasure to use, though the finishing touches on the telescope weren't as good as they could have been – giving it a more of a 'prototype' feel. Yet these can be considered minor issues as it is extremely practical. The excellent optical performance and compact, lightweight nature of this Explore Scientific Dobsonian remain true to John Dobson's original design ethos while also giving a design update and superb performance. Ⓢ

VERDICT

ASSEMBLY	★★★★☆
BUILD & DESIGN	★★★☆☆
EASE OF USE	★★★★☆
FEATURES	★★★★☆
OPTICS	★★★★☆
OVERALL	★★★★☆

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FIRST **light**

See an interactive 360° model of this mount at **www.skyatnightmagazine.com/AZ-EQ5GT**

Sky-Watcher AZ-EQ5GT mount

Flexibility defines this multi-configuration, mid-range mount

WORDS: PAUL MONEY

VITAL STATS

- **Price** £999
- **Mount** AZ-EQ Go-To
- **Payload capacity** 15kg for EQ and 15kg plus 15kg for dual scope altaz mode
- **Controller** Synscan V4 handset with dual AZ/EQ firmware
- **Database** 42,900 objects
- **Tracking speed** Sidereal, solar and lunar
- **Power requirements** 12V DC 3A
- **Tripod** Pier tripod with adjustable legs
- **Weight** Mount 7.7kg, tripod 6.1kg
- **Ports** 2x snap camera, St-4 autoguider, USB
- **Extras** Two 3.5kg counterweights, counterweight extension bar, second saddle
- **Supplier** Optical Vision
- **www.**opticalvision.co.uk
- **Tel** 01359 244200

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Telescope mounts have traditionally been of two designs, the simple altaz or the German equatorial, where one axis is aligned with the polar axis of the Earth for extended periods of tracking. However, in the past few years we've seen a trend for mounts combining both into one multipurpose system, especially with the advent of computerised tracking. Sky-Watcher embraced this combined approach with the AZ-EQ6GT earlier this year, and have followed it with mid-range AZ-EQ5GT.

The AZ-EQ5GT is supplied with a pier tripod, SynScan V4 handset, power cable, dec. cable, two camera snap cables, a second Vixen-style saddle, two 3.5kg counterweights and a counterweight extension bar. The pier tripod attaches to the mount using a flexible extension that is collapsible and has extendible legs for extra height. The pier is hollow and saves on weight by having three slots cut into it, which we found useful for putting the handset in when it wasn't being used. A minor quibble is that, good as the pier tripod is, we did find it a little flexible on the rubber foot pads. This was mainly noticeable when we installed our heaviest telescope and counterweights, although the vibrations did quickly dampen down.

Unlike its larger cousin the AZ-EQ6GT, the AZ-EQ5GT has no in-built polarscope; nor is one supplied in the box. For most of our tests we used the mount without a polarscope, as by looking along the polar axis we were able to roughly polar align the mount well enough for visual use. An option on the handset allows for an improvement of polar alignment once an initial two- or three-star alignment routine has been performed and we found this greatly improved the performance of the mount in EQ mode.

SKY SAYS... Altaz mode is ideal for visual use, EQ for tracking accuracy or if you intend to do any imaging

The SynScan V4 handset is slightly larger than the V3 handset and its firmware can be flash updated, however unlike previous versions there is no power input on the handset so it does have to be connected to the mount when performing the upgrade. With 42,900 objects in its database there are plenty of targets to explore. Alternatively, with a suitable cable (sold separately) the mount can also be controlled either by computer or smart device.

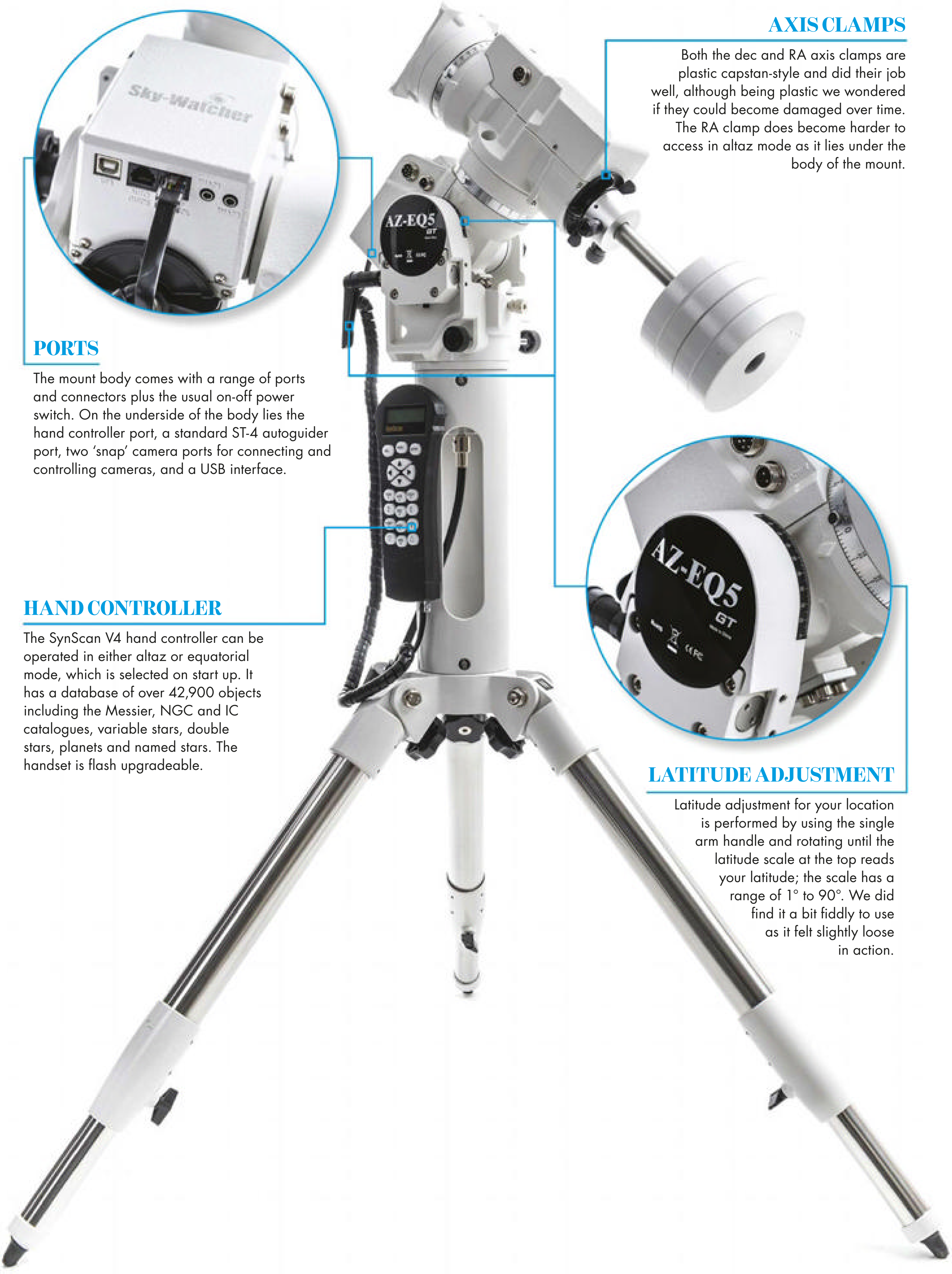
Alignment options

In EQ mode we did find the accuracy better, especially when we performed a three-star alignment and in the SynScan menu added several extra stars to enhance the pointing and tracking accuracy. In altaz mode you can select either a 'brightest star' alignment where you choose an area of the sky for your first star alignment, or the two-star alignment where you can select a star from the offered list to begin alignment. The altaz mode ▸

ONE TELESCOPE OR TWO?

Just like its big brother the AZ-EQ6GT, the AZ-EQ5GT gives you three mounts in one package depending on how you configure it. It can be set up as a typical equatorial mount so you can undertake long-exposure astrophotography; it also can also be configured as an altaz for simple viewing sessions, either with a single telescope or as a dual setup via the supplied second mounting saddle.

The second mounting saddle takes the place of the counterweights and is easy to install. Note that in altaz configuration you should always attach the largest telescope to the main body of the mount and add the smaller one to the secondary saddle. This versatility can be useful for public stargazing events where two scopes can be mounted side by side to maximise viewing pleasure (not to mention viewing potential) without setting up two separate mounts for the job. Changing between the EQ and altaz configurations is relatively straightforward and takes just a few minutes.



AXIS CLAMPS

Both the dec and RA axis clamps are plastic capstan-style and did their job well, although being plastic we wondered if they could become damaged over time. The RA clamp does become harder to access in altaz mode as it lies under the body of the mount.

PORTS

The mount body comes with a range of ports and connectors plus the usual on-off power switch. On the underside of the body lies the hand controller port, a standard ST-4 autoguider port, two 'snap' camera ports for connecting and controlling cameras, and a USB interface.

HAND CONTROLLER

The SynScan V4 hand controller can be operated in either altaz or equatorial mode, which is selected on start up. It has a database of over 42,900 objects including the Messier, NGC and IC catalogues, variable stars, double stars, planets and named stars. The handset is flash upgradeable.

LATITUDE ADJUSTMENT

Latitude adjustment for your location is performed by using the single arm handle and rotating until the latitude scale at the top reads your latitude; the scale has a range of 1° to 90°. We did find it a bit fiddly to use as it felt slightly loose in action.

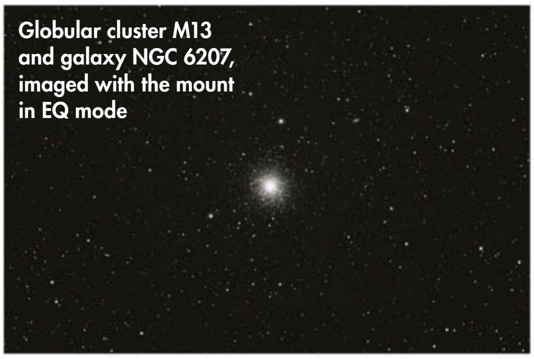
FIRST **light**

PIER TRIPOD

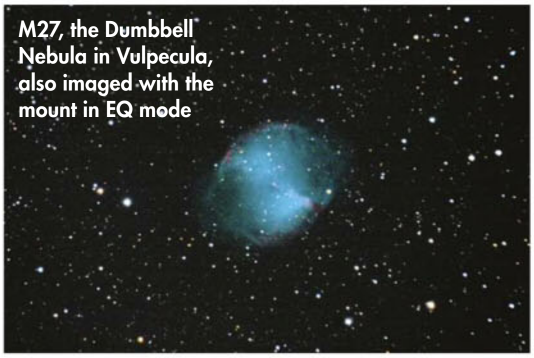
This is a new tripod for Sky-Watcher mounts. It is extremely portable in that the legs can be folded up back alongside the pier, making it quite compact for transportation. The pier saves weight with cut-away slots, which we found useful as a place to put the handset when not in use.

SKY SAYS…
Now add these:

1. Polarscope
2. 17Ah power tank
3. GPS mouse



Globular cluster M13 and galaxy NGC 6207, imaged with the mount in EQ mode



M27, the Dumbbell Nebula in Vulpecula, also imaged with the mount in EQ mode

▸ is ideal for visual use, EQ if you need tracking accuracy or intend to do any imaging.

For our night sky tests we used an Equinox 80ED refractor with 2-inch 26mm and 9mm eyepieces, and a SkyMax 180 Pro Maksutov with a 1.25-inch 26mm and 9mm eyepieces. We were able to track the bright star Regulus in Leo for over half an hour using a 9mm eyepiece in our Equinox 80ED with only slight deviation from the centre of the view, and our pointing accuracy tests worked well in both the equatorial and altaz modes. We took tours of the sky in both modes by selecting a range of objects – including stars, Messier and NGC objects, and the planets above the horizon at the time of review – and checked how well they were centred.

In EQ mode the mount can support 15kg of equipment: that's 15kg of telescope for purely visual use or 15kg including the camera, autoguider and other kit for astrophotography. Swapping to altaz mode the mount can take up to two 15kg scopes on each saddle, making it ideal for use at public events. Overall the mount performed well regardless of the configuration we used; Sky-Watcher has yet again come up with a useful addition to its family of mounts. S

VERDICT	
ASSEMBLY	★★★★☆
BUILD & DESIGN	★★★★☆
EASE OF USE	★★★★☆
GO-TO ACCURACY	★★★★☆
STABILITY	★★★☆☆
OVERALL	★★★★☆

WWW.THESECRETSTUDIO.NET, PAUL MONEY X 2

FIRST light

See an interactive 360° model of this camera at
www.skyatnightmagazine.com/Skyris132M

Celestron Skyris 132M monochrome

Solar System imager

Swapping the common CCD chip for a CMOS makes this an intriguing device

WORDS: MARTIN LEWIS

VITAL STATS

- **Price** £485
- **Sensor** Aptina ARO132AT CMOS sensor
- **Pixels** 1,280x960; 3.75μm square
- **Dimensions** 42x42x39mm
- **Weight** 102g
- **Extras** C-mount to 1.25-inch adaptor, C-mount to CS-mount adaptor, USB 3.0 cable, software CD
- **Supplier** David Hinds
- **www.**celestron.uk.com
- **Tel** 01525 852696

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The Celestron Skyris 132M Solar System Imager is the latest high-speed digital video camera from the Celestron and The Imaging Source. Devices such as this are capable of recording a stream of frames, the best of which can then be stacked and sharpened to produce an image largely free from the blurring effect of our atmosphere.

In common with the Celestron NexImage Burst camera (reviewed in the February issue) the Skyris 132M contains an Aptina ARO132 CMOS chip with a generous 1,280x960 pixels. However it has a different housing and also supports USB 3.0, enabling faster download speeds and allowing more frames to be gathered in a given time.

The 132M is a monochrome camera; a colour variant, the 132C, is available for the same price. That means if you want to capture colour shots of the planets you'll need to take separate red, green and blue exposures and combine them, and to achieve that you need to add a filter wheel to the front of the camera – the end result is much heavier than a one-shot colour device.

The camera can be operated using The Imaging Source's iCap camera control program, which is supplied on a CD in the box, or the freeware program FireCapture (**http://firecapture.wonderplanets.de**). After installing the camera driver from the CD we used both programs to record video on laptops running Windows XP and Windows 7. Capture speeds were hampered somewhat by their slow hard drives, but shorter runs were faster in FireCapture with its frame buffering feature. We checked on Celestron's website and the drivers on the disc were actually more recent versions than those available online.

SKY SAYS...
The big chip allowed us to capture a large area of the Moon at high resolution

Getting to grips with gain

We tested the camera on the almost full Moon, using it in conjunction with an 8.75-inch Newtonian and fitted with a 742nm infrared filter in front of the camera nosepiece to reduce the blurring effects of the atmosphere. The big chip allowed us to capture a large area of the Moon at high resolution, while the high sensitivity allowed us to use a low gain to reduce noise but still use short exposures at the longer wavelengths we were imaging in, where a CMOS chip's sensitivity falls off.

For the Sun we used a similar set-up, swapping the infrared filter in front of the camera and a white light solar filter in front of the telescope. ▸

QUICKER CAPTURE RATES

The Skyris 132M has USB 3.0 connectivity, allowing faster video data transfer rates when imaging. This allows you to gather more frames in a short space of time, provided the object is bright and you don't need exposure times longer than the frame time. More frames means less noise and a higher number of really good frames available for stacking, leading to better final images.

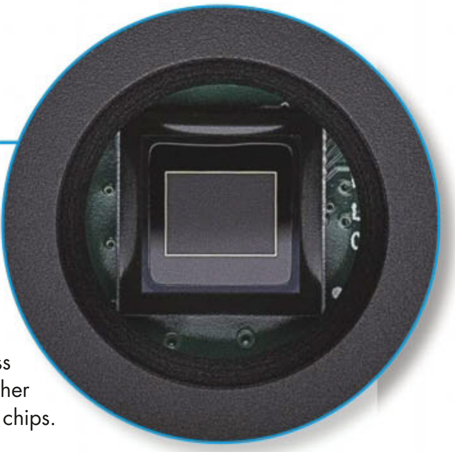
With a computer with a fast hard drive and USB 3.0 capability, we found that with a bright object we could achieve frame rates of 60 frames per second (fps) at full frame – twice the maximum speed achievable with USB 2.0. The camera also has hardware selectable 'region of interest' capability enabling reduced frame sizes but even faster transfers of over 400fps. On an older USB 3.0 laptop we could reach these speeds for short periods using the frame-buffering capability that FireCapture allows, but a more modern laptop should capture directly to the hard drive at this speed without buffering.

BODY

The camera body is small, lightweight and has heat fins to help keep the camera cool and minimise noise. However a tripod mounting screw hole would have been useful so you could use the camera off the scope with a suitable lens.

MANUAL

The 15-page manual is particularly well laid out and clear. It covers system requirements, driver and software installation, how to use the camera to capture videos and how to process them in RegiStax. There are also some useful general tips.



CMOS CHIP

The Skyris 132M is one of a growing number of Solar System cameras that use a CMOS chip rather than the more traditional CCD. Recent advances mean these chips are now often cheaper, create less noise and offer higher sensitivity than CCD chips.

1.25-INCH ADAPTOR

The Skyris 132M comes with a C-mount to 1.25-inch adaptor, which screws to the front of the camera and is threaded for filters for RGB imaging. The distance to the chip from the front of the camera without the 5mm spacer supplied is the standard CS-mount distance of 12.5mm.

FIRST light

USB 3.0 CABLE

Unlike some video cameras that come with leads that are impractically short, the Skyris 132M is packaged with a 3m USB 3.0 cable. The plug is secured to the body of the camera with two thumbscrews, preventing accidental disconnection. The cable is backwards compatible with USB 2.0 sockets.

▸ With the high surface brightness and high sensitivity of the camera we could drop the gain to the minimum to reduce noise. We managed to capture a nicely detailed sunspot at the edge of the solar disc, as well as faculae and solar granulation.

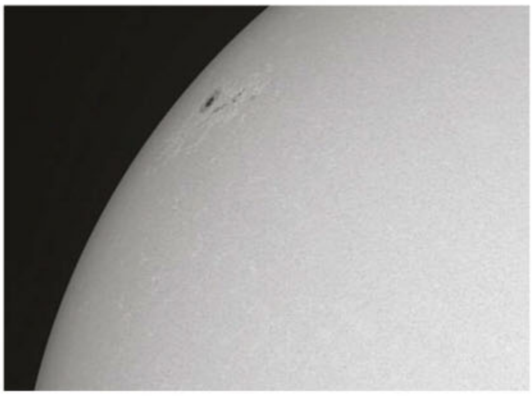
Jupiter, sitting high overhead, was a bit more troublesome. At a gain setting of 60 per cent or less the planet suffered from edge-ringing artefacts due to the higher levels of image processing required to bring out detail on the planet's disc. To combat this we had to run the camera at a higher gain, but this led to the image being quite noisy. On warmer nights a vertical noise pattern across the field was faintly visible. The chip also has no protective window and small dust particles often settled on it while in use; these had to be blown off. Eventually, by using a gain of 75 per cent on a steady night and an 18-inch telescope, we gathered enough red, green and blue frames to later make an RGB image showing detail within the Great Red Spot and a wealth of other fine features. Ⓢ

VERDICT	
BUILD & DESIGN	★★★★☆
CONNECTIVITY	★★★★☆
EASE OF USE	★★★☆☆
FEATURES	★★★★☆
IMAGING QUALITY	★★★★☆
OVERALL	★★★★☆

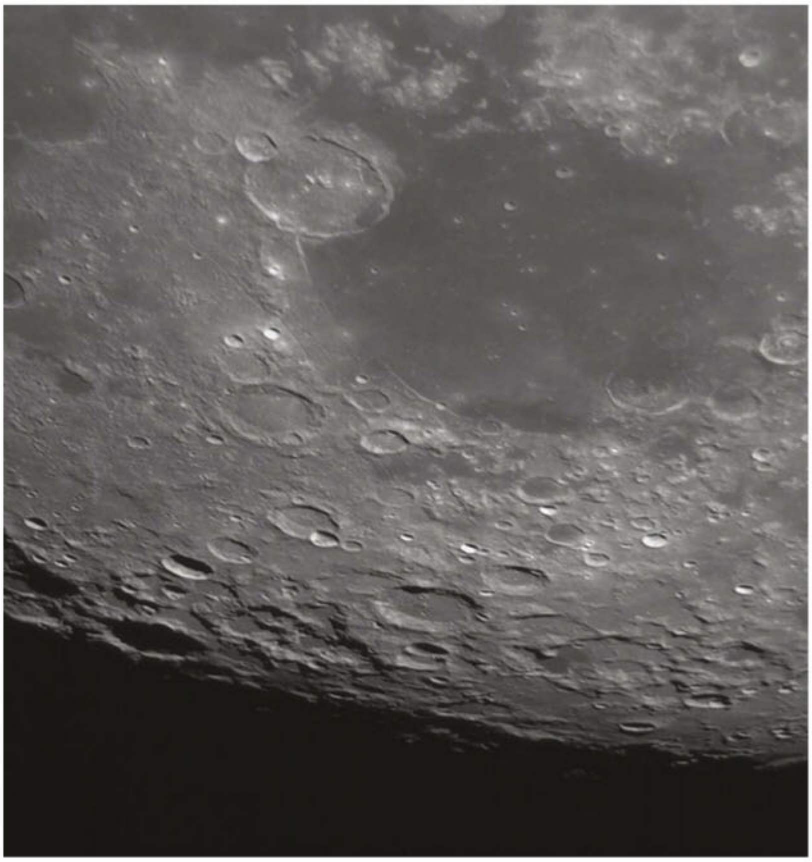
SKY SAYS...
Now add these:

1. Skyris five-position 1.25-inch filter wheel
2. 1.25-inch LRGB filter set
3. 1.25-inch infrared-cut filter

▲ Our final colour shot of Jupiter with the Great Red Spot



▲ The Sun's limb at full frame, revealing a sunspot



▲ Our full frame shot of the myriad craters surrounding the Moon's south pole

WWW.THESECRETSTUDIO.NET, ASTROPHOTOS: MARTIN LEWIS X 3

Books

New astronomy and space titles reviewed

RATINGS
★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

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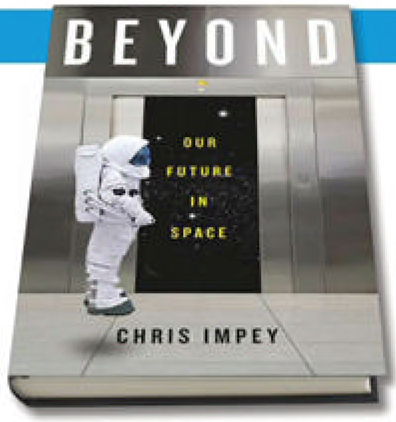


Beyond
Our Future in Space

Chris Impey
W.W Norton & Company, Inc.
£17.99 ● HB

Past performance is the best predictor of future achievement, argues University of Arizona professor Chris Impey. Will humanity colonise the Solar System, and then the stars beyond? No doubt about it, he claims, once you look back to human prehistory, and see how swiftly the first Homo sapiens spread from east Africa to cover the rest of the planet. Impey does not deny that today NASA is in the doldrums, but takes hope in the growing private space sector. His second analogy is the 1990s internet: previously monopolised by the government and military, it was very suddenly turbocharged and democratised by an influx of commercial ideas and investment.

He goes on to spell out the companies, the technologies and the destinations set to make space colonisation happen, pointing out along the way that constructing a space elevator – by far the most efficient means of reaching Earth orbit – would cost only half the International Space Station's price tag. But Impey thinks humanity is destined to go a lot further still: the final section covers the technical demands of building a starship, and the likelihood of finding alien life. Short fictional interludes convey the kind of existence our pioneering descendants will enjoy.

There is little truly new here, but this is still an engagingly written and stimulating thesis. To play devil's advocate, it still took tens of thousands of years for humanity to find the reaches of planet Earth. With resource depletion, overpopulation and climate change, our descendants are unlikely to enjoy such a leisurely timescale. And humans never did settle Antarctica. Might space turn out to be an even less hospitable version of the white continent?

In the 1960s we talked a lot about settling the oceans depths as well, but not anymore.

The book's positivity is marred by some careless slips. To take a trivial example, TV comedian Stephen Colbert campaigned to have the International Space Station's Node 3 named after him, not its toilet (he eventually made do with the 'COLBERT' orbital treadmill instead). More tragically, the three lost cosmonauts of Soyuz 11 had already commenced reentry when their cabin depressurised – the book's phrase 'preparing for reentry' implying they had been still in orbit when disaster struck.

★★★☆☆

Growing pressures on our planet mean it is vital for us to boldly go, and quickly

ISTOCK

SEAN BLAIR *writes for the European Space Agency's website*

Reader price £16.99, subscriber price £16.50 P&P £1.99 Code: S0615/1 (until 24/07/15)

TWO MINUTES WITH CHRIS IMPEY

What was your inspiration for the book?
As an astronomer I depend on space telescopes and robotic probes, but human space travel seemed to me quixotic and very expensive. Over most of its history it was driven by superpower rivalry and military considerations. But I've watched the private space industry emerge with keen interest, and these new players will shake things up; their innovations will fuel scientific discovery as well as tourism and commerce. The visionaries are back in the driving seat again. This will take space activity in unexpected directions.

What does our future in space look like?
Progress is so rapid that it's difficult to reliably predict more than two decades out. The year 2015 for space is like 1995 for the internet. SpaceX or Virgin Galactic may become the Google and Amazon of the space industry, or the future titans may not yet be on the scene. In the Wild West phase, fortunes will be made and people will die. It will not be dull.

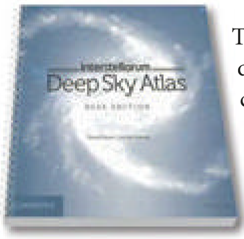
How much of the book is grounded in fact?
Space travel is rooted in the brutal physics of the rocket equation, which dictates how difficult it is to put any large payload into orbit. Humans will always be difficult and expensive to keep sustained in the unforgiving environment of space. In the book I project propulsion technologies that might allow us to travel the Solar System, and hibernation options that might one day let us travel to the stars. Science fact is just as exciting as science fiction.

CHRIS IMPEY *is deputy head of the astronomy department at the University of Arizona*

Interstellarum Deep Sky Atlas

BOOK OF THE MONTH

Tonald Stoyan & Stephan Schurig
Oculum/Cambridge University Press
£59.99 ● PB



The arrival of a new deep-sky atlas is always cause for excitement amongst astronomers, but the marketing team behind this one have gone into overdrive to announce its virtues with a dedicated website and YouTube video. The authors are keen to portray this atlas as different from those that have gone before, and it's not all hype.

Comprising 114 double-page charts 280mm deep by 265mm wide, plus several detail pages, this is a large atlas but its generous spiral binding allows it to lie flat for easy scrutiny in the field. With a resolution of 1.5cm per degree on the main pages and even higher on the detail pages, the charts are packed with a wide range of objects. Included are more unusual denizens of the deep, such as dark nebulae, Abell clusters and van den Burgh reflection nebulae, in addition to the Messier, NGC and IC catalogue objects that you would expect. Many common names appear among the pages, adding appeal for beginners.

Uniquely, the authors have introduced a set of shaded colour codes to indicate object visibility through a range of telescopes apertures, although these are a little subjective as so much depends on the observer's visual acuity and local sky conditions. In the field, the heavy quality pages were resilient to dew and the chart detail very readable by red torchlight, although the visibility colour coding was less easy to view under these conditions.

This beautifully drawn and produced atlas will take pride of place in many observer's collections, being suitable for both beginners and experienced observers.

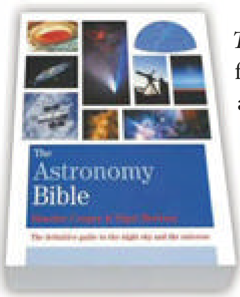
★★★★★

STEVE RICHARDS *is* BBC Sky at Night Magazine's *Scope Doctor*

Reader price £54.99, subscriber price £51.99
P&P £1.99 Code: S0615/2 (until 24/07/15)

The Astronomy Bible

Heather Couper & Nigel Henbest
Philip's
£14.99 ● PB



The Astronomy Bible from Heather Couper and Nigel Henbest deals with a cornucopia of astronomical subjects, and is one of those very important books in astronomy. It has the sense of a neutron star about it: it is the size of a teapot stand but it is crammed with every conceivable aspect concerning the night sky. This book ought to weigh a trillion tonnes. But despite the number of subjects covered, *The Astronomy Bible* is in no way scant on detail. All entries hold a satisfying depth of information.

I say this is one of the important books in astronomy because you can't help feel a great sense of how it will inspire interest in the oldest and greatest of the sciences, the way Patrick Moore described how, as a nine year old, he read *The Story of the Solar System* by GF Chambers. His interest in astronomy was sealed from then on, and it is the way I felt as a lad reading *The Observer's Book of Astronomy*, unable to put it down.

The Astronomy Bible is a superb example of one these books, which do so much to ignite an interest. Interests that'll stay sparked too, as the book's level of detail means it will be referred back to whether learning about how to star hop or the kind of event that creates a microquasar. Who knows, perhaps a 12 year old starting high school could end up being the first astronaut on Mars in the 2030s. The breadth of engaging information inside this book will serve many a budding astronaut well.

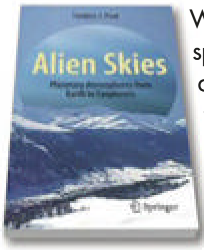
★★★★★

JON CULSHAW *is an impressionist and writer of our monthly* Exoplanet Excursions *column*

Reader price £13.99, subscriber price £13.50
P&P £1.99 Code: S0615/3 (until 24/07/15)

Alien Skies

Frédéric J Pont
Springer
£16.95 ● PB



What would a futuristic space probe see as it descended into the fiery depths of a hot Jupiter. Or what would happen to Earth's atmosphere if our planet was suddenly plucked from its orbit and dropped into the one that Mars inhabits? Rather than simply describing the atmospheres of alien worlds, in *Alien Skies* Frédéric J Pont really helps the reader to visualise what conditions would be like on another planet.

The book begins with a very clear description of atmospheric science on our planet, such as the effects of temperature and pressure, and the role that volcanic gases and the water cycle play in keeping Earth habitable. Pont then applies this knowledge to Venus and Mars, describing the various steps that would need to take place to transform the Earth into a planet akin to our inhospitable neighbours.

Pont then takes the reader on a hypothetical trip to a hot Jupiter – a giant ball of gas that orbits its star in a matter of days. This alien world has clouds of glass and metal, and its sun sets with an eerie blue hue. Next we embark on a tour of strange terrestrial planets; one enveloped completely in ice, one water world, and another that wanders the depths of space with no star to call home.

Negative points are few. There is the occasional lapse with units when metric is switched to imperial, which can make the descriptions of atmospheric height momentarily confusing. Also, some of the images are a bit repetitive, although this book is well illustrated overall.

★★★★☆

AMANDA DOYLE *is a freelance science writer and a postdoctoral researcher at the University of Warwick*

Reader price £15.50, subscriber price £14.99
P&P £1.99 Code: S0615/4 (until 24/07/15)

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

[redacted]

1 Astronomy Double Helix Science Kit

Price £19.99 • **Supplier** Curious Minds 01436 670806 • www.curiousminds.co.uk

Aimed at young astronomers, this kit's 21 experiments include making your own telescope, launching rockets and assembling models of the International Space Station.

2 Baader Astrosolar Binocular Filter

Price £26-£44 • **Supplier** The Widescreen Centre 020 7935 2580 • www.widescreen-centre.co.uk

These ready-made filters feature Baader AstroSolar Safety Film are available from 50mm to 100mm in 10mm increments; they can also be used with a camera – note that for binoculars you need two, one for each lens.

3 Space Bedding Sets

Price £59.61 • **Supplier** Etsy www.etsy.com/uk/shop/artbedding

Sleep under the stars every night with these celestial-themed bedding sets. Each pack includes a duvet, fitted sheet and pillowcases.

4 Orion 1.25-inch Three-Piece Planetary Imaging Filter Set

Price £399 • **Supplier** SCS Astro 01823 665510 • www.scsastro.co.uk

Get better planetary portraits with this triplet of filters – ultraviolet, infrared and methane – each with an anti-reflective coating. Includes a plastic case with die-cut foam insert.

5 SkEye Pro

Price £3.69 • **Supplier** Android https://play.google.com

An advanced planetarium that gives real-time coordinates to help you set up your scope. The app includes support for comets, a full catalogue of objects and can track satellites.

6 Geoptik RGB Artificial Star

Price €107.44 • **Supplier** Geoptik +39 045 9250989 • www.geoptik.com

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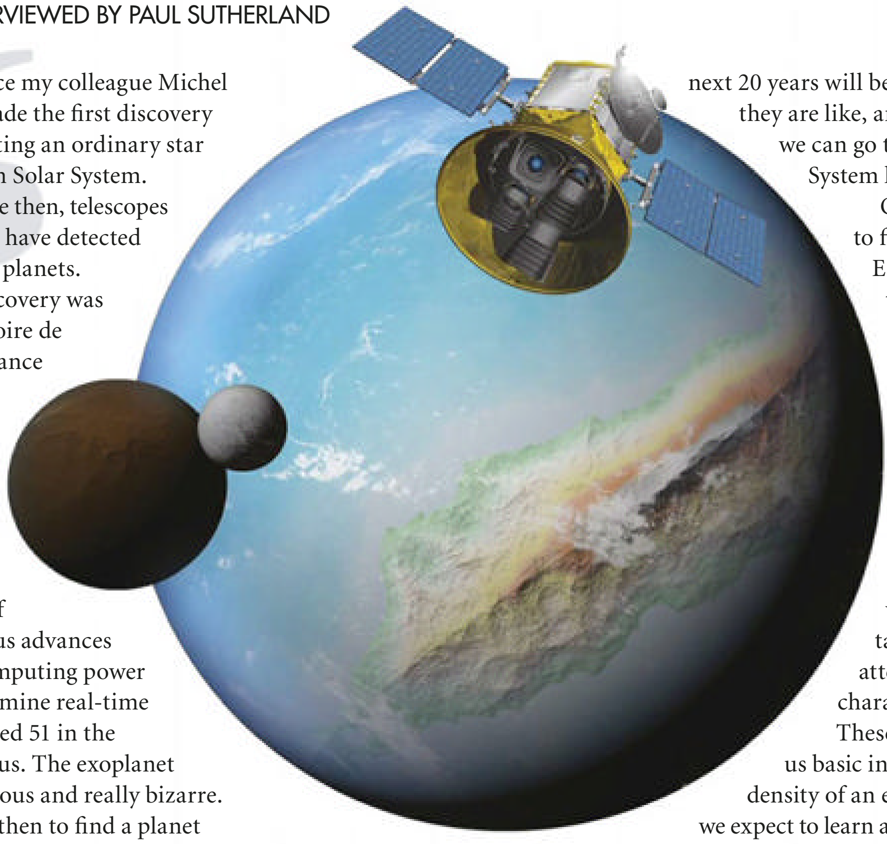
WHAT I REALLY WANT TO KNOW IS…
Where next in our search for alien worlds?

Didier Queloz found the first world around a main sequence star 20 years ago; now he wonders what we might learn by 2035

INTERVIEWED BY PAUL SUTHERLAND



TESS is one of several upcoming planet hunters; the space scope will monitor half a billion stars in the hope of glimpsing the telltale drop in brightness that denotes a planet in transit

ISTOCK, NASA

It is 20 years since my colleague Michel Mayor and I made the first discovery of a planet orbiting an ordinary star outside our own Solar System. That was in 1995. Since then, telescopes on Earth and in space have detected more than 1,000 such planets.

Our pioneering discovery was made at the Observatoire de Haute-Provence in France using the radial velocity method, which measures the wobble of a star as it is orbited by another body. Our find came when it did thanks to a number of small but simultaneous advances in technology and computing power that allowed us to examine real-time data from a star labelled 51 in the constellation of Pegasus. The exoplanet was immediately obvious and really bizarre. No one had expected then to find a planet with an orbit lasting just four days. Many people just didn't believe it.

More discoveries soon followed. The next revolution in exoplanet hunting came a few years later with a technique called the transit method, where the exoplanet reveals itself by passing in front of its home star. The first such find, in 1999, confirmed a planet already discovered by radial velocity. It confirmed to the skeptics that exoplanets were real and not imaginary.

Our weird Solar System

NASA's Kepler space telescope has been the ultimate transit machine, discovering many hundreds of exoplanets on its mission in space. Most of the planets it has found have been different from those in our Solar System, and we don't really know much about them. But we are coming to the very interesting conclusion that our own Solar System is rather unusual. The search for exoplanets was meant to help us understand the Solar System, and yet the more we look outside, the less we understand ourselves.

Research so far has demonstrated that just about every star has planets. The focus in the next 20 years will be to understand what they are like, and to see how far we can go to finding a Solar System like our own.

One major goal is to try to find a twin planet to Earth. Kepler was meant to do that and failed: instead it showed us that we were too focused on trying to find something equivalent to our own world. In the next decade new space telescopes called TESS, CHEOPS and PLATO will launch. They will target nearby stars and attempt to discover and characterise their planets. These missions will give us basic information such as the density of an exoplanet. After that we expect to learn about its atmosphere, including its chemical composition. We will even be able to observe clouds. So this is the challenge for the next 10 to 20 years. In time we will find an object like Earth, with a thin atmosphere, and then one day we might even see some evidence in that atmosphere of life.

The upcoming James Webb Space Telescope will play a very important role in this, as will the new giant ground instruments such as the European Extremely Large Telescope in Chile. These new giant telescopes will, in time, be able to image nearby exoplanets directly and tell us much more about these alien worlds. Developing technology will allow us to check how they rotate, their seasons and climate, and see whether they are habitable. It is not very clear whether we would recognise signs of life, or how long that will take, but if we keep looking, we should find something.

We are working really hard right now to find targets for the new generation of giant telescopes to observe. One thing that is clear, however, is that we must avoid being too target-oriented over the next 20 years. The story of science, as already demonstrated with exoplanets, is that we have to be ready for the unexpected.

ABOUT DIDIER QUELOZ

Prof Didier Queloz works at the Battcock Centre for Experimental Astrophysics at the University of Cambridge. His mission is to detect and characterise exoplanets, and so advance our understanding of their formation, structure, and habitability.

The Southern Hemisphere in June

With Glenn Dawes

WHEN TO USE THIS CHART

1 JUN AT 00:00 UT
15 JUN AT 23:00 UT
30 JUN AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

JUNE HIGHLIGHTS

June opens with Jupiter and Venus 21° apart, in the northwest early evening sky. Venus is the lower and brighter of the planets. They slowly converge and at month end are only 0.5° apart – the same as the apparent width of the Moon. The Moon also visits these planets as a thin crescent on the 20th and 21st, and – from southeast Australia – occults Uranus on the morning of the 12th. The planet vanishes behind the Moon's bright limb around 05:00 EST and emerges from the dark limb 70 minutes later.

STARS AND CONSTELLATIONS

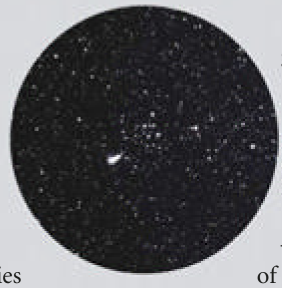
Nestled between Scorpius and Triangulum Australe is the ancient constellation of Ara, the altar on which the centaur (Centaurus) was supposed to slay the wolf (Lupus). It is easily recognised, with seven stars ranging from mag. +2.8 to +4.0 arranged in an 'open book' shape. Ara's most distinctive feature is the pair of 3rd-magnitude stars forming the southern end of the book's spine: separated by only 1°, Beta (β) and Gamma (γ) Arae are yellow and white respectively.

THE PLANETS

Jupiter and Venus continue to steal the evening show (see June's highlights). Saturn is also on offer, due north around 23:00 EST mid-month and visible all night. Although Neptune now rises before midnight it is still best observed in the morning sky, while Uranus is at its best in the pre-dawn. Mercury returns to the dawn sky in the latter half of June; look low in the northeast where it can be seen passing through the Hyades. It is only 2° from Aldebaran (Alpha (α) Tauri) on the 24th.

DEEP-SKY OBJECTS

Ara offers a feast of open clusters. Starting at mag. +3.3 Gamma (γ) Arae, a brilliant small telescope double star, jump 11° northwest, towards the bend in the tail of Scorpius. Here lies a bright galactic knot, which includes sparse cluster NGC 6200 (RA 16h 44.1m, dec. –47° 28'), composed of around a dozen 8th- to 9th-magnitude stars. Being superimposed on a very busy galactic star field, it is best found using binoculars.

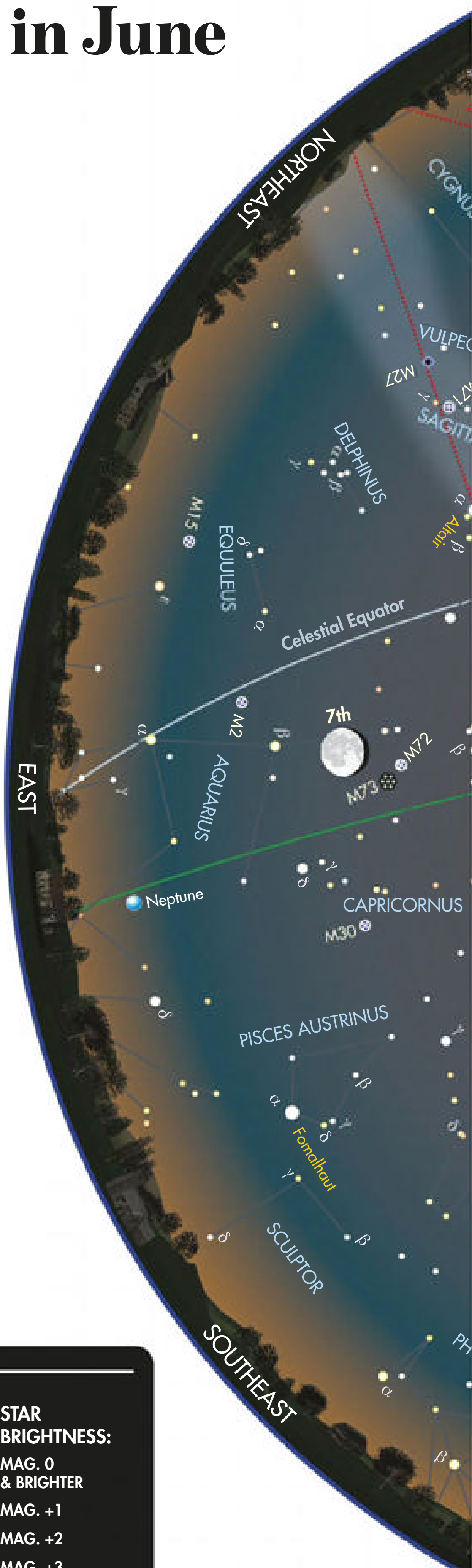


Look 0.5° northeast to find open cluster NGC 6204 (RA 16h 46.3m, dec. –47° 01'; pictured), a group of 11th- to 12th-magnitude stars in a distinctive triangle. The real gem, only 8 arcminutes away, is Hogg 22, a group of eight stars in a single curved line 3 arcminutes long. These two clusters are attractive in low-power fields (50x).

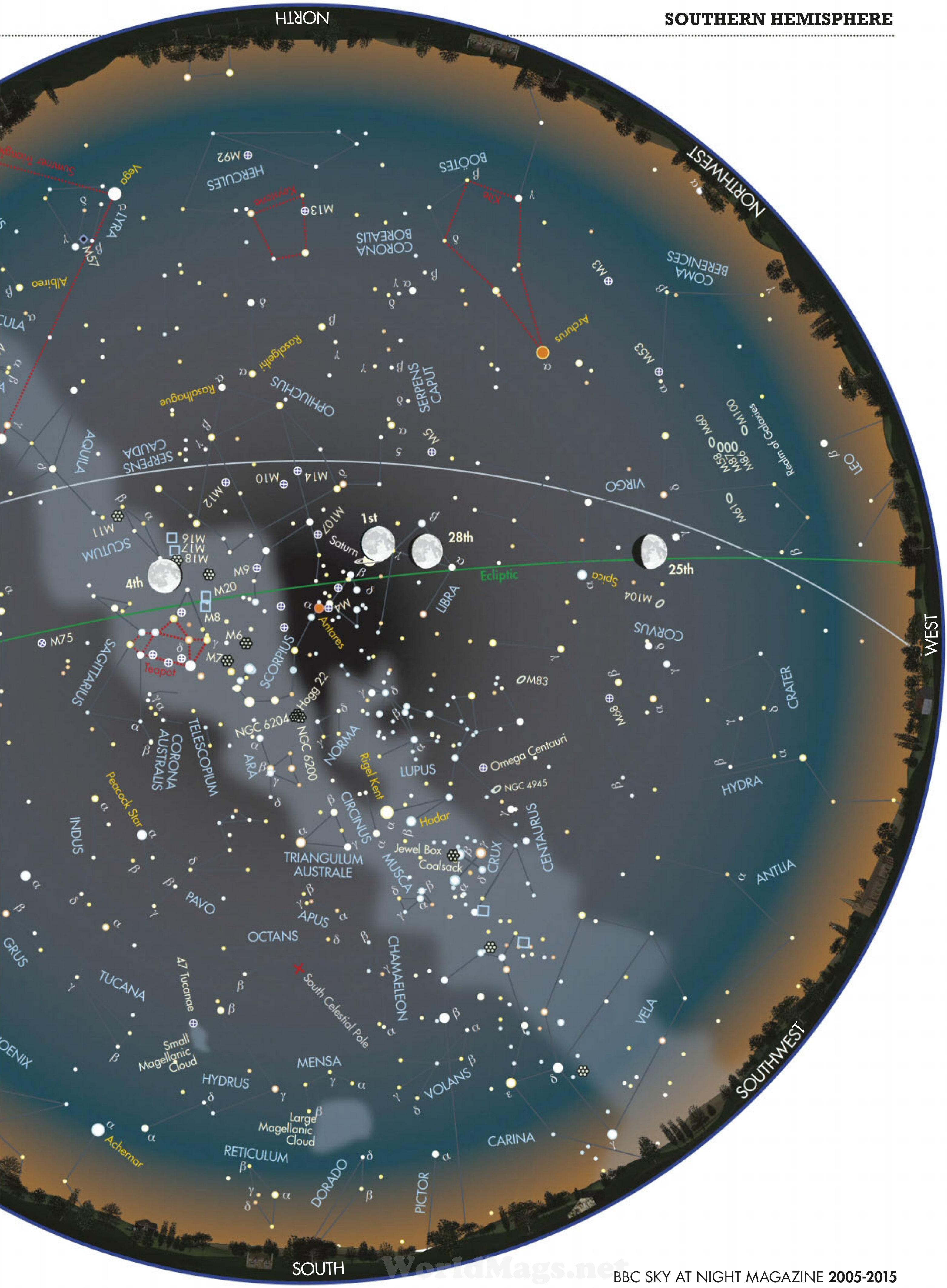
CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER



ROBERTO MURA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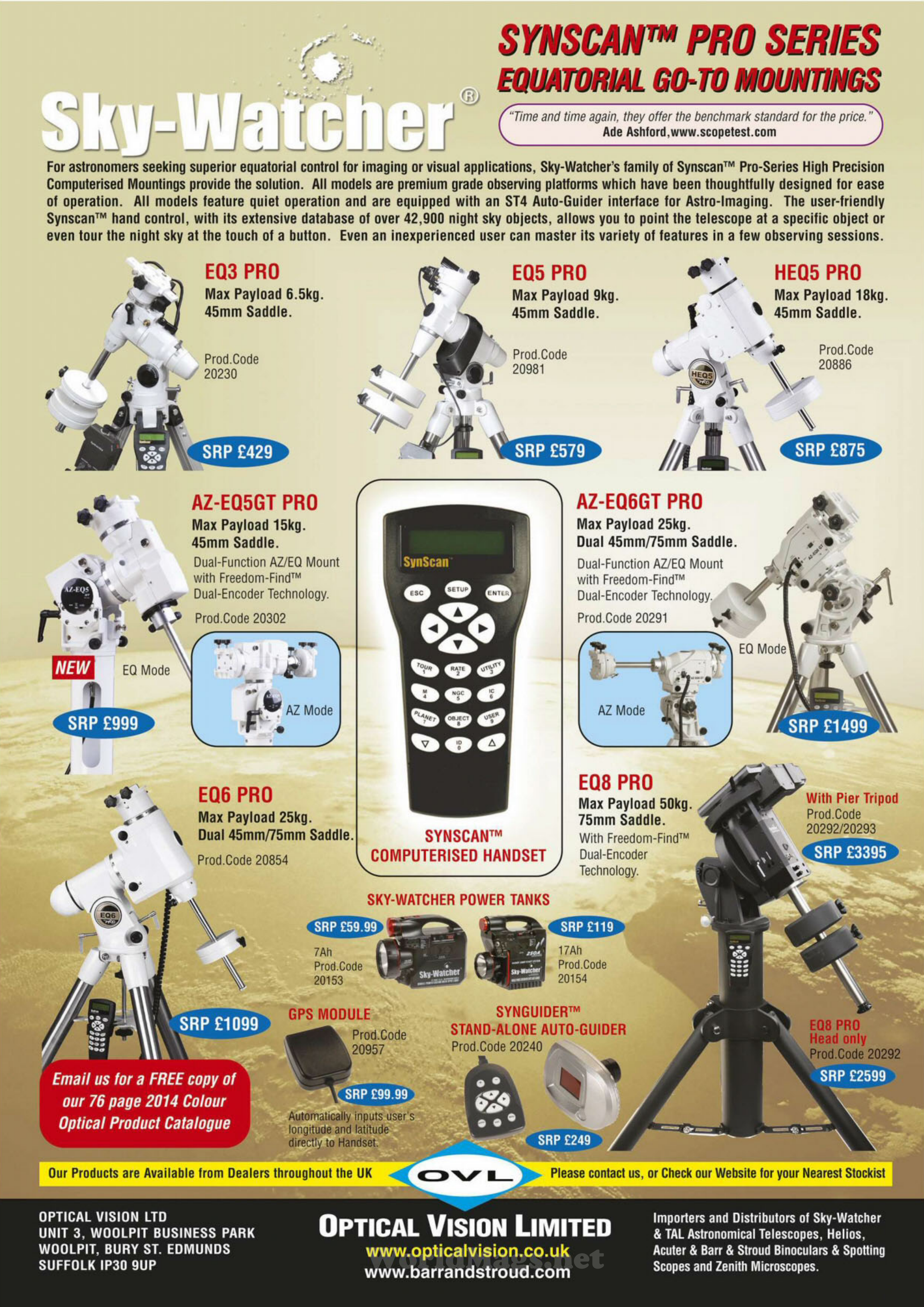

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